NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
0201-20-2325

March 1957

NBS REPORT
4794

SPECTROPHOTOMETRIC AND COLORIMETRIC

STUDY OF COLOR TRANSPARENCIES

OF SOME NATURAL OBJECTS

By

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To

U. S. Department of the Air Force
Aerial Reconnaissance Laboratory
Wright Air Development Center
Wright-Patterson Air Force Base, Ohio

Contract No. AF 33(616) 52-21
Task No. 62104

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

PREFACE

This is one of a series of NBS reports of spectrophotometric and colorimetric work done under NBS Project 0201-20-2325 entitled Color Reconnaissance Studies, financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, under Air Force Contract No. AF 33(616) 52-21. It was coordinated with Air Force Contract No. AF 33(616)-262 under Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland. The present report resulted from several requests for spectrophotometric and colorimetric tests of color transparencies of some natural objects.

Harry J. Keegan
Project Leader

SPECTROPHOTOMETRIC AND COLORIMETRIC STUDY OF COLOR TRANSPARENCIES OF SOME NATURAL OBJECTS

Harry J. Keegan, John C. Schleter, Gladys M. Haas*, and Wiley A. Hall, Jr.

Abstract

This is a comparison of the effect that natural formations or objects have upon the various emulsion layers that comprise color positive and color negative photographic films. Spectral transmittance measurements and colorimetric computations are made and reported on these effects. In addition, visible and near infrared spectral directional reflectance measurements are reported for one of these photographed natural objects; namely sand, together with several other soils, sands, and barks of trees. Also reported are C.I.E. chromaticity coordinates, Munsell renotations, daylight reflectances or daylight transmittances, ISCC-NBS color designations, Lovibond notations of these materials, and color differences between wet and dry sand and their corresponding color transparencies.

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* Miss Haas is at present employed at the Mare Island Naval Shipyard, San Francisco, California.

Contents

I. Introduction

The overall objective of this Air Force investigation is stated as follows: "To develop by visible, near infrared, and near ultraviolet spectrophotometry, methods for the detection of objects from color reconnaissance; to study the colors, tonal contrast, and color separation necessary in aerial photography to yield maximum information; to determine the wavelength region at which the film manufacturer should strive to obtain maximum sensitivity to yield clear separation of an object from its adjacent area rather than to yield true color fidelity; to determine the characteristics required in a sensitized material for the rapid and accurate extraction of this information".

This particular report pertains to the spectral transmissive and colorimetric properties of color transparencies of various types of natural formations usually seen in ground and aerial photographs when reproduced on one-, two-, and three-emulsion color positive and color negative films. These are some of the same films reported by Dr. O'Neill [1, 2].*

Also included in this report are the visible and near infrared spectral directional reflectance measurements of several natural objects; such as, sand, soil, and barks of trees.

The method of measurement and computation is that requested in the original project proposal and used in six previous reports of this project [3 - 8]. A companion report (NBS Report 4953, in preparation) will deal in the same manner with photographs of man-made objects of the same types of color films [9].

II. Material

All of the material of this report was furnished by Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland. The reflecting materials, bark of trees, sands, and soils, were selected by him and removed from his property at the head of Broad Creek, South River, Chesapeake Bay, Maryland. The sands and soils were brought to the NBS by him on June 13, 1953, and the barks of trees on March 3, 1956.

The transparent materials of this report are in the form of color transparencies. When received from Dr. O'Neill the films had been processed and numbered. Accompanying the color transparencies was a notebook containing information on them, such as exposure number, kind of Ansco film, identification of the object, Weston lightmeter reading, aperture, shutter speed, date of photography, and occasional notes. The pertinent parts of this information are included in Table I of this report together with a "sample number" which will be used to identify the sample whenever it is used either in text, tables, or figures.

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* Numbers in brackets refer to bibliography on page 86 of this report.

According to Dr. O'Neill, the types of films used to photograph natural formations were: (1) three one-color, one-emulsion films (red, green, and blue sensitive emulsions used in Ansco Daylight Color); (2) three two-color, two-emulsion films (red and green, green and blue, and blue and red sensitive emulsions used in Ansco Daylight Color); (3) one three-color, three-emulsion film (Ansco Daylight Color); and (4) one three-color, three-emulsion, color negative film (Ansco Plenacolor).

In this report, these films will be identified as follows: RGB (Ansco Daylight Color), RG (red and green sensitive emulsions used in Ansco Daylight Color), GB (green and blue sensitive emulsions used in Ansco Daylight Color), BR (blue and red sensitive emulsions used in Ansco Daylight Color), R (red sensitive emulsion used in Ansco Daylight Color), G (green sensitive emulsion used in Ansco Daylight Color), B (blue sensitive emulsion used in Ansco Daylight Color), and Plena (Ansco Plenacolor color negative film).

These films were used to photograph: gray and white clouds; wet gravel; green leaves of black walnut and locust trees; seaweed in water; blue and gray sky; yellow and green sycamore tree leaves; green vegetation leaves; muddy water; water under nimbus clouds; and wet and dry yellowish quartz sand from Rodger's Quarry near Annapolis, Maryland. Most of the photographs were made with the same film but with different shutter speed, aperture setting, or both. Only the yellowish quartz sand, wet and dry, were photographed at normal exposure and at two settings of overexposure, and on all eight types of color film.

In Dr. O'Neill's report [2], five other films were stated to have been used on other objects, but they were not used on this study of sands. These were: "Magenta layer (color negative)", "Cyan layer (color negative)", "D-342 Special 2-layer film 10", and "Ansco Tungsten (3-layer) factor 14", and later in the same report "Three-layer, three-color film (Anscochrome)".

Table I. Identifications of Natural Objects(*) and Color Transparencies of Natural Objects.

Sample Number	Exposure Number	Description	Shutter Speed (seconds)	Aper-ture	Film	Date Taken
(1)	--	(*)White Sand, Rodger's Quarry (Wet)	---	---	---	---
(2)	--	(*)Yellowish Quartz Sand, Rodger's Quarry (Wet)	---	---	---	---
(3)	--	(*)Commercial (Zonalite) "Vermiculite" (Wet)	---	---	---	---
(4)	--	(*)White Sand, Rodger's Quarry (Dry)	---	---	---	---
(5)	--	(*)Yellowish Quartz Sand, Rodger's Quarry (Dry)	---	---	---	---
(6)	--	(*)Commercial (Zonalite) "Vermiculite"(Dry)	---	---	---	---
(7)	--	(*)Collington Sandy Loan (Damp)	---	---	---	---
(8)	W-68	Blue Sky	1/50	f/16	RGB	7-20-53
(9)	W-69	Gray Cloud	1/50	f/16	RGB	"
(10)	W-70	Gray Sky, Thunderstorm Coming (to NE)	1/50	f/16	RGB	"
(11)	W-71	Gray Sky, Thunderstorm Coming (to S)	1/50	f/16	RGB	"
(12)	W-72	Water Under Nimbus Clouds	1/50	f/16	RGB	"
(13)	W-73	Seaweed; Scene of Seaweed in Water (telephoto; sunlight, hazy, gray clouds)	1/50	f/11	RGB	"
(14)	W-73	Water; Scene of Seaweed in Water (telephoto; sunlight, hazy, gray clouds)	1/50	f/11	RGB	"
(15)	W-300	Muddy Water, Normal Exposure			RGB	7-7-53
(16)	W-301	Muddy Water, Over Exposure			RGB	"
(17)	W-302	Muddy Water, Over Exposure			RGB	"
(18)	W-177	Cumulus White Cloud, Under Exposure	1/100	f/22	BR	7-3-53
(19)	W-178	Cumulus White Cloud, Normal Exposure	1/100	f/11	BR	"
(20)	W-179	Cumulus White Cloud, Over Exposure	1/100	f/8	BR	"
(21)	W-180	Blue Sky, Under Exposure	1/100	f/22	BR	"
(22)	W-181	Blue Sky, Normal Exposure	1/100	f/11	BR	"
(23)	W-182	Blue Sky, Over Exposure	1/100	f/8	BR	"
(24)	W-80	Leaves of Sycamore (Platanus occidentalis, L.) Yellow			RGB	7-20-53
(25)	W-81	Leaves of Sycamore (Platanus occidentalis, L.) Yellow, Close-up			RGB	"
(26)	W-121	Leaves of Sycamore (Platanus occidentalis, L.) Green			RGB	7-24-53
(27)	W-122	Leaves of Sycamore (Platanus occidentalis, L.) Green, Close-up			RGB	"
(28)	W-123	Leaves of Black Oak (Quercus velutina, Lam.) Green			RGB	"
(29)	W-131	Leaves of Black Oak (Quercus velutina, Lam.) Green, Close-up			RGB	7-29-53
(30)	W-143	Green Vegetation, Leaves in Light, Normal Exposure	1/100	f/16	GB	7-2-53
(31)	W-143	Green Vegetation, Leaves in Shade, Normal Exposure	1/100	f/16	GB	"

Table I (Continued)

Sample Number	Exposure Number	Description	Shutter Speed (seconds)	Aper- ture	Film	Date Taken
(32)	W-144	Green Vegetation, Leaves in Light, Over Exposure	1/100	f/8	GB	7-2-53
(33)	W-144	Green Vegetation, Leaves in Shade, Over Exposure	1/100	f/8	GB	"
(34)	W-145	Green Vegetation, Leaves in Light, Over Exposure	1/100	f/5.6	GB	"
(35)	W-145	Green Vegetation, Leaves in Shade, Over Exposure	1/100	f/5.6	GB	"
(36)	W-174	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Light, Under Exposure	1/100	f/11	BR	7-3-53
(37)	W-174	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Shade, Under Exposure	1/100	f/11	BR	"
(38)	W-175	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Light Normal Exposure	1/100	f/5.6	BR	"
(39)	W-175	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Shade Normal Exposure	1/100	f/5.6	BR	"
(40)	W-176	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Light Over Exposure	1/100	f/4	BR	"
(41)	W-176	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Shade Over Exposure	1/100	f/4	BR	"
(42)	W-872	Wet Sand, Normal Exposure	1/100	f/8	RGB	7-15-53
(43)	W-873	Wet Sand, Over Exposure	1/100	f/5.6	RGB	"
(44)	W-874	Wet Sand, Over Exposure	1/100	f/4	RGB	"
(45)	W-890	Wet Sand, Normal Exposure	1/100	f/8	RG	"
(46)	W-891	Wet Sand, Over Exposure	1/100	f/5.6	RG	"
(47)	W-892	Wet Sand, Over Exposure	1/100	f/4	RG	"
(48)	W-899	Wet Sand, Normal Exposure	1/100	f/8	GB	"
(49)	W-900	Wet Sand, Over Exposure	1/100	f/5.6	GB	"
(50)	W-901	Wet Sand, Over Exposure	1/100	f/4	GB	"
(51)	W-881	Wet Sand, Normal Exposure	1/100	f/8	BR	"
(52)	W-882	Wet Sand, Over Exposure	1/100	f/5.6	BR	"
(53)	W-883	Wet Sand, Over Exposure	1/100	f/4	BR	"
(54)	W-935	Wet Sand, Normal Exposure	1/200	f/22	R	"
(55)	W-936	Wet Sand, Over Exposure	1/200	f/16	R	"
(56)	W-937	Wet Sand, Over Exposure	1/200	f/11	R	"
(57)	W-926	Wet Sand, Normal Exposure	1/100	f/16	G	"

Table I (Continued)

Sample Number	Exposure Number	Description	Shutter Speed (seconds)	Aper-ture	Film	Date Taken
(58)	W-927	Wet Sand, Over Exposure	1/100	f/11	G	7-15-53
(59)	W-928	Wet Sand, Over Exposure	1/100	f/8	G	"
(60)	W-908	Wet Sand, Normal Exposure	1/100	f/11	B	"
(61)	W-909	Wet Sand, Over Exposure	1/100	f/8	B	"
(62)	W-910	Wet Sand, Over Exposure	1/100	f/5.6	B	"
(63)	W-917	Wet Sand, Normal Exposure	1/100	f/11	Plena	"
(64)	W-918	Wet Sand, Over Exposure	1/100	f/8	Plena	"
(65)	W-919	Wet Sand, Over Exposure	1/100	f/5.6	Plena	"
(66)	W-875	Dry Sand, Normal Exposure	1/100	f/11	RGB	"
(67)	W-876	Dry Sand, Over Exposure	1/100	f/8	RGB	"
(68)	W-877	Dry Sand, Over Exposure	1/100	f/5.6	RGB	"
(69)	W-893	Dry Sand, Normal Exposure	1/100	f/11	RG	"
(70)	W-894	Dry Sand, Over Exposure	1/100	f/8	RG	"
(71)	W-895	Dry Sand, Over Exposure	1/100	f/5.6	RG	"
(72)	W-902	Dry Sand, Normal Exposure	1/100	f/8	GB	"
(73)	W-903	Dry Sand, Over Exposure	1/100	f/5.6	GB	"
(74)	W-904	Dry Sand, Over Exposure	1/100	f/4	GB	"
(75)	W-884	Dry Sand, Normal Exposure	1/100	f/11	BR	"
(76)	W-885	Dry Sand, Over Exposure	1/100	f/8	BR	"
(77)	W-886	Dry Sand, Over Exposure	1/100	f/5.6	BR	"
(78)	W-938	Dry Sand, Normal Exposure	1/200	f/22	R	"
(79)	W-939	Dry Sand, Over Exposure	1/200	f/16	R	"
(80)	W-940	Dry Sand, Over Exposure	1/200	f/11	R	"
(81)	W-929	Dry Sand, Normal Exposure	1/100	f/16	G	"
(82)	W-930	Dry Sand, Over Exposure	1/100	f/11	G	"
(83)	W-931	Dry Sand, Over Exposure	1/100	f/8	G	"
(84)	W-911	Dry Sand, Normal Exposure	1/100	f/11	B	"
(85)	W-912	Dry Sand, Over Exposure	1/100	f/8	B	"
(86)	W-913	Dry Sand, Over Exposure	1/100	f/5.6	B	"
(87)	W-920	Dry Sand, Normal Exposure	1/100	f/11	Plena	"
(88)	W-921	Dry Sand, Over Exposure	1/100	f/8	Plena	"
(89)	W-922	Dry Sand, Over Exposure	1/100	f/5.6	Plena	"
(90)	W-944	Wet Gravel, Normal Exposure	1/100	f/5.6	RGB	"
(91)	W-945	Wet Gravel, Over Exposure	1/100	f/4	RGB	"
(92)	W-946	Wet Gravel, Over Exposure	1/100	f/2.8	RGB	"
(93)	---	(*)Bark, Outer, Scrub Pine (Pinus virginiana, Mill.)	---	---	---	3-3-56
(94)	---	(*)Bark, Inner, Scrub Pine (Pinus virginiana, Mill.)	---	---	---	"
(95)	---	(*)Bark, Outer, White Oak (Quercus alba, L.)	---	---	---	"
(96)	---	(*)Bark, Inner, White Oak (Quercus alba, L.)	---	---	---	"

III. Preparation of samples

The reflecting materials such as the bark of trees were placed against the integrating sphere of the spectrophotometer and held there with the usual spring fastener furnished with the instrument. The sands and soils were poured into special clear glass containers which in turn were fastened to the integrating sphere of the instrument. Distilled water was later added to the glass container of dry sands and soils for the wet sample measurement. The Collington Sandy Loam, Sample No. (7) was damp when received at the NBS. The sample was measured under the moisture condition in which it was received; no additional distilled water was used.

Two devices were designed (JCS) and constructed for the measurements of color transparencies. The first device illustrated in Figure 1 is used to assist in trimming the color transparencies to proper size for measurement. This rectangular plastic box is connected to an air suction line. The top cover of the box is perforated, and when the valve to the air suction line is opened, the film placed over the perforations is held flat and firmly in place. A plastic plate, made to the correct dimensions desired for the trimmed film (2-1/4 by 2-1/4 inches), is placed on the film and the color transparency is trimmed with a razor blade, using the plastic plate as a guide. The plywood base upon which the plastic box and the valve are located is cut away beneath the box so that the device may be placed over a light table allowing the color transparency to be fully illuminated during the trimming operation.

The second device illustrated in Figure 2* is used to position the color transparency and hold it flat during measurement on the spectrophotometer. It is attached to the base plate of the integrating sphere of the spectrophotometer, in place of the transmission sample compartment. By the use of this device, the position of the color transparency during measurement can be accurately set in three dimensions by means of racks and pinions or a screw, and the position noted accurately by means of three scales attached to the device. The color transparency and the felt covered film holder plates can be oriented so that the light beam can pass through any of the four quadrants or through the center of the transparency. The scales indicated in the figure are as follows: V indicates the up-down position of the color transparency for measurement; H indicates the left-right position; and S indicates the position away from and toward the integrating sphere. In use, the positions of the V and H scales were first set and the holder moved as close to the integrating sphere as possible along the S scale. The positions of measurement were accurately noted and recorded (GMH), together with the orientation of the film in the holder, so that at any future date the exact position of the color transparency during measurement could be redetermined. These data are given in Appendix D of this report. Also included in Appendix D is a diagram (Figure 31) which can be used to indicate the area of the color transparency actually measured.

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* This device was constructed in the machine shop of the NBS Photometry and Colorimetry Section by Mr. G. H. Limparis.

Figure 1. Suction device to hold color transparency accurately in place while being trimmed to 2-1/4 x 2-1/4 inch size required for sample holder.

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Figure 2. Positioning device to hold photographic transparency firmly in place and to note accurately the three dimensional placement of the film during measurement. This is especially important for the measurement of a field scene.

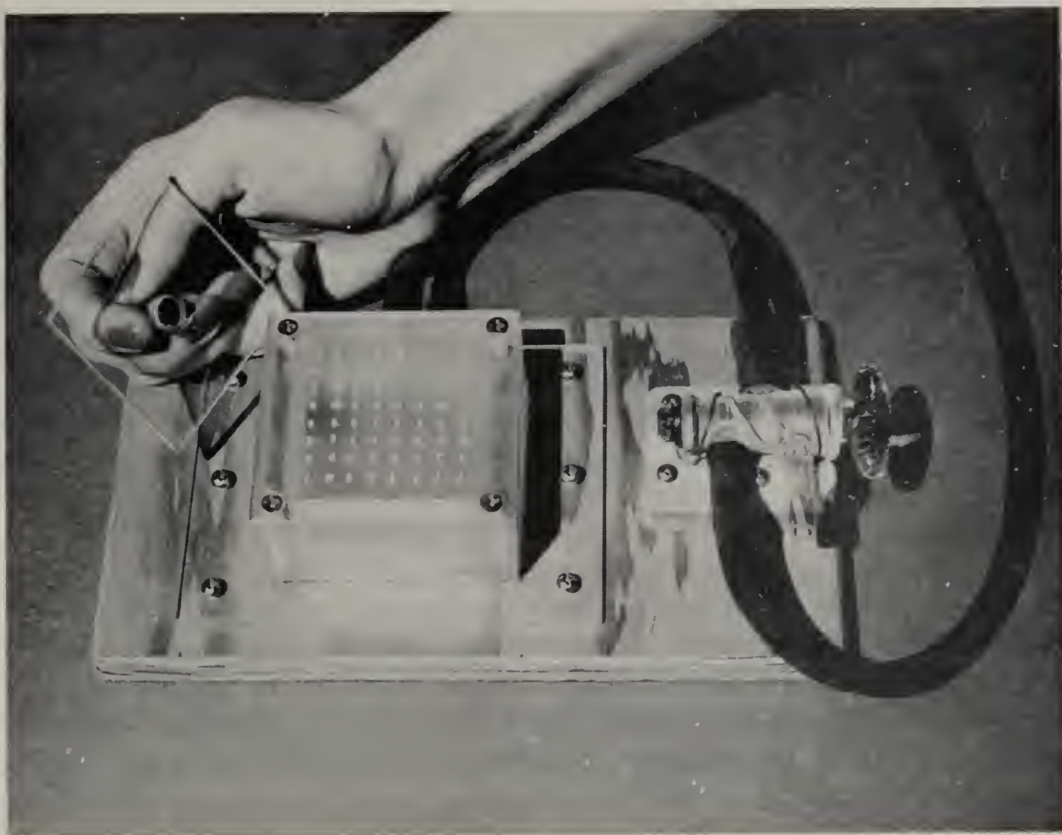


FIGURE 1

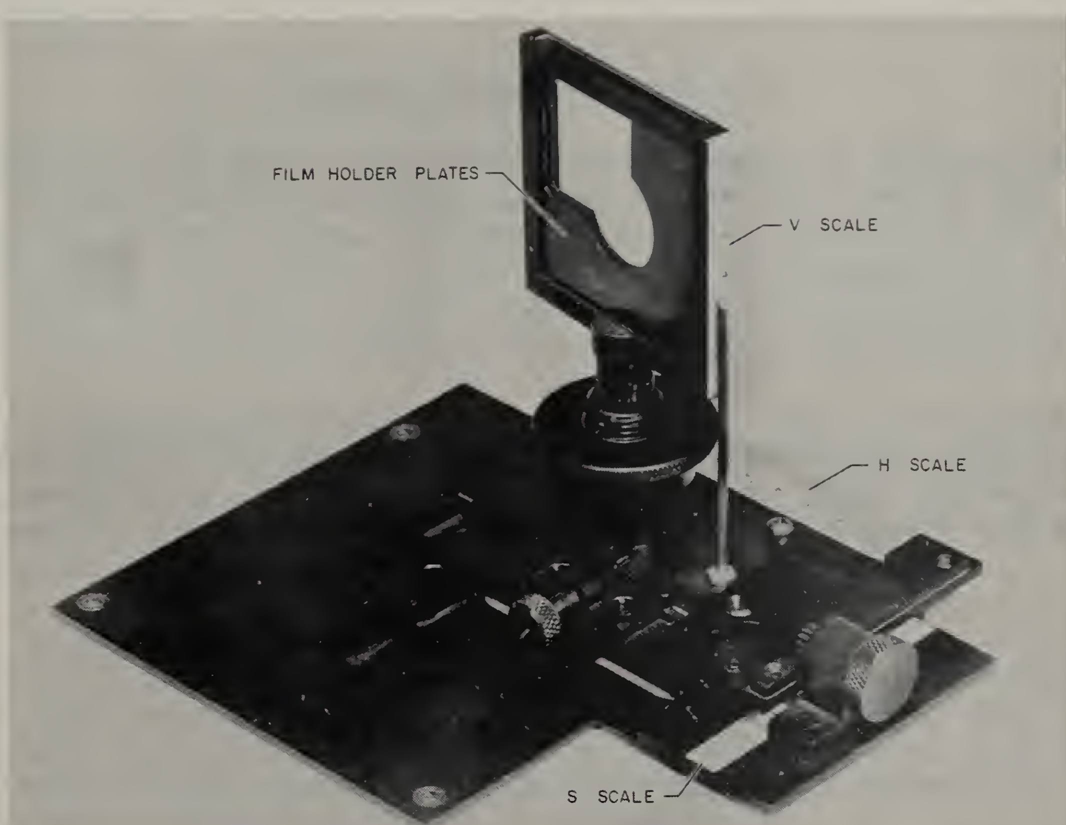


FIGURE 2

IV. Spectrophotometric Measurements

For the eleven reflecting materials such as the barks of trees, the white and yellow sands, and the soils, measurements of spectral directional reflectance were made for the visible and near infrared spectral ranges (400 to 1080 millimicrons) on the General Electric recording spectrophotometer [10, 11] . These spectral directional reflectance measurements were made for the condition of included specular component of the reflected radiant energy. Slits of approximately 10 millimicrons of spectral width were used for the measurements in the visible spectrum, 400 to 750 millimicrons, and 20 millimicrons of spectral width for the near infrared spectrum, 730 to 1080 millimicrons.

For the eighty-five color transparencies of natural objects, measurements of spectral transmittance for the visible spectrum (400 to 750 millimicrons) were made on the same General Electric recording spectrophotometer, equipped with slits approximating 10 millimicrons of spectral width. For these spectral transmittance measurements, recordings were made with calibration curves (didymium, zero, and 100% curves) for making wavelength and photometric scale corrections [12, 13].

Each of the eight curve sheets for the eleven reflecting materials was read and tabulated at each ten millimicron interval between 400 and 1080 millimicrons. Each of the thirteen curve sheets for the eighty-five color transparencies was read and corrected at each ten millimicron interval between 400 and 750 millimicrons.

V. Spectrophotometric Results

The results of the spectrophotometric measurements of spectral directional reflectance or spectral transmittance of this report are shown on the twenty-one Ozalid copies of the original recordings from the General Electric recording spectrophotometer. These Ozalid copies are a part of Appendix C of this report; seventeen of them are for the visible spectrum, 400 to 750 millimicrons, and four of them are for the near infrared spectrum, 730 to 1080 millimicrons.

Values of spectral directional reflectance were read at 10 millimicron intervals from 400 to 1080 millimicrons for each of the eleven determinations of the six specimens of sand, soil, and bark of trees. These eleven sets of spectrophotometric data are listed in Appendix B of this report, and are illustrated in Figures 3 and 4.

Values of spectral transmittance were corrected and read at 10 millimicron intervals from 400 to 750 millimicrons for each of the eighty-five determinations made on the seventy-eight color transparencies of clouds, sky, water, sand, seaweed, gravel, green and yellow vegetation, and other natural objects. These eighty-five sets of spectrophotometric data are listed in Appendix B of this report, and are illustrated in Figures 5 through 16.

Figure 3. Visible and near infrared spectral directional reflectance of wet sands (solid curves), dry sands (dashed curves), and damp soil (variable dashed curve).

(1) Wet White Sand, Rodger's Quarry

(2) Wet Yellowish Quartz Sand, Rodger's Quarry

(3) Wet Commercial (Zonalite) "Vermiculite"

(4) Dry White Sand, Rodger's Quarry

(5) Dry Yellowish Quartz Sand, Rodger's Quarry

(6) Dry Commercial (Zonalite) "Vermiculite"

(7) Damp Collington Sandy Loam

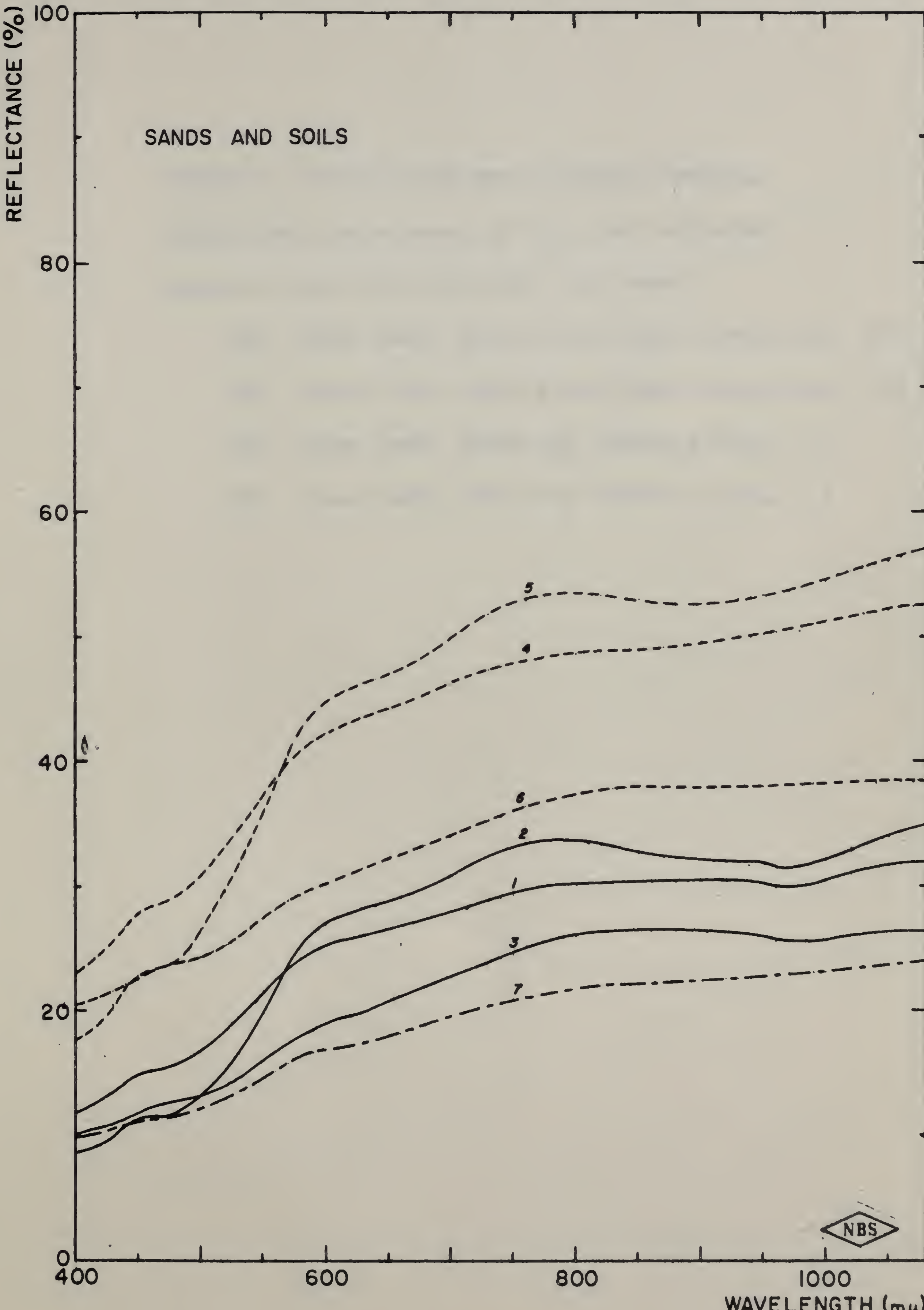

REFLECTANCE (%)
SANDS AND SOILS
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH (mμ)
5
4
6
2
1
3
7
NBS

FIGURE 3

Figure 4. Visible and near infrared spectral directional reflectance of the inner and outer barks of scrub pine and white oak trees.

(93) Outer Bark, Scrub Pine (Pinus virginiana, Mill.)

(94) Inner Bark, Scrub Pine (Pinus virginiana, Mill.)

(95) Outer Bark, White Oak (Quercus alba, L.)

(96) Inner Bark, White Oak (Quercus alba, L.)

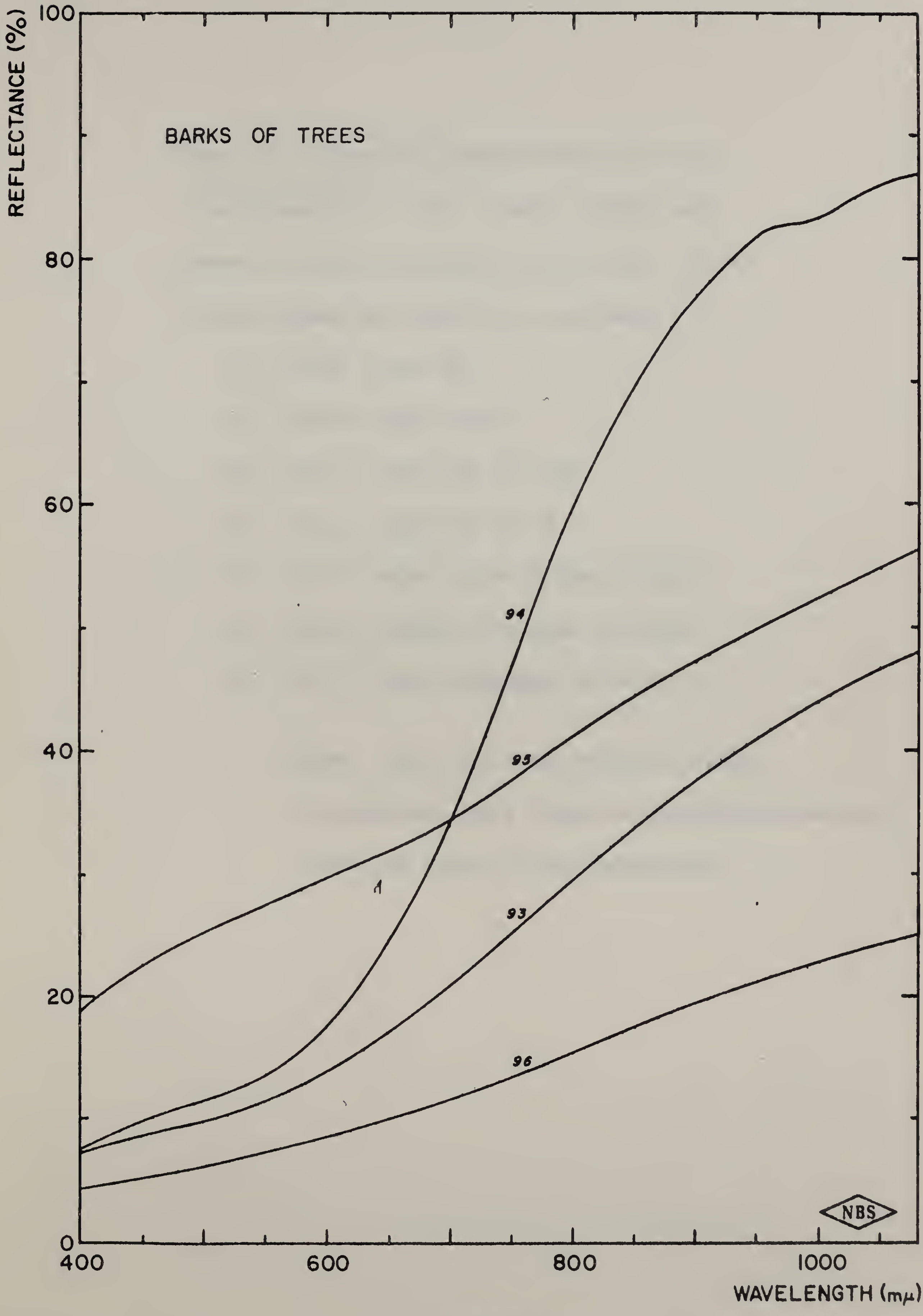


FIGURE 4

Figure 5. Spectral transmittance of color transparencies of sky, clouds, water, and seaweed on Ansco daylight color film. (For shutter speed and aperture, see Table I).

(8) W-68 Blue Sky

(9) W-69 Gray Cloud

(10) W-70 Gray Sky (to NE)

(11) W-71 Gray Sky (to S)

(12) W-72 Water under Nimbus Clouds

(13) W-73 Seaweed, Seaweed in Water

(14) W-73 Water, Seaweed in Water

(Note. When the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

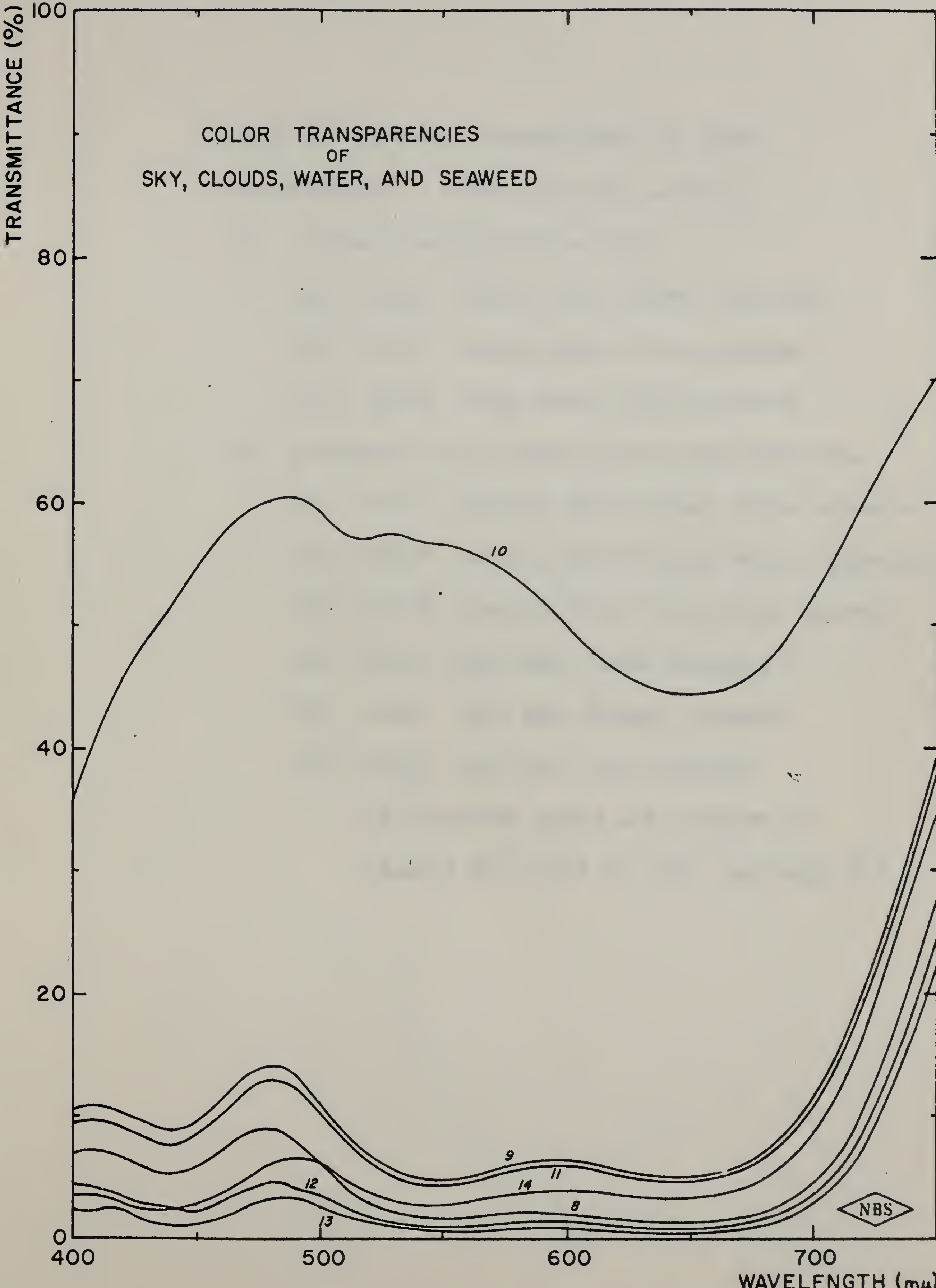

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
SKY, CLOUDS, WATER, AND SEAWEED
10
9
11
14
8
12
13
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 5

Figure 6. Spectral transmittance of color transparencies of water, clouds, and sky.

a) On Ansco Daylight Color Film

(15) W-300 Muddy Water, Normal exposure

(16) W-301 Muddy Water, Over exposure

(17) W-302 Muddy Water, Over exposure

b) On Special Ansco Blue and Red Sensitive Film

(18) W-177 Cumulus White Cloud, Under exposure

(19) W-178 Cumulus White Cloud, Normal exposure

(20) W-179 Cumulus White Cloud, Over exposure

(21) W-180 Blue Sky, Under exposure

(22) W-181 Blue Sky, Normal exposure

(23) W-182 Blue Sky, Over exposure

(For shutter speed and aperture of Sample Nos. (18) to (23), see Table I.)

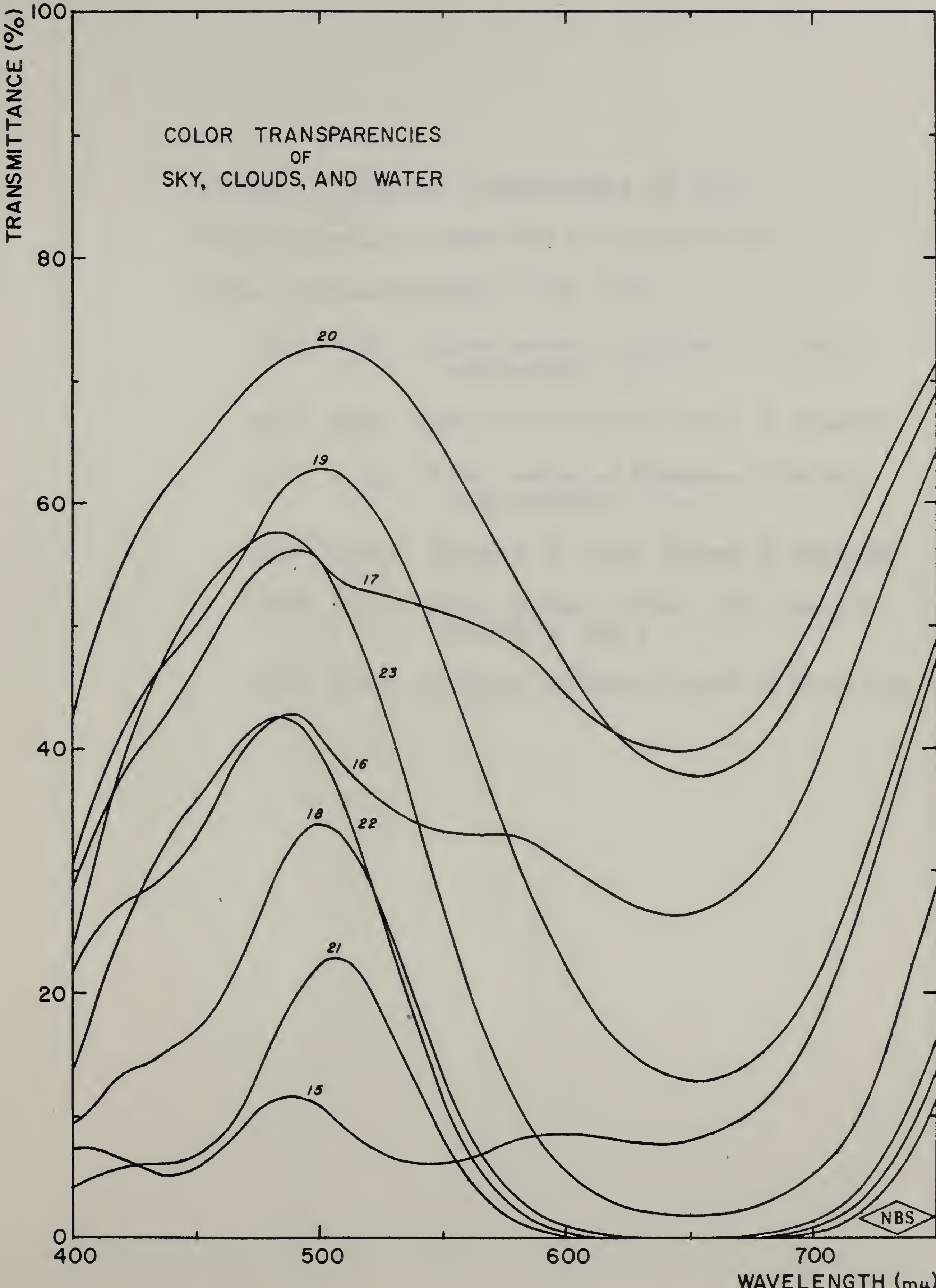

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
SKY, CLOUDS, AND WATER
20
19
17
23
16
18
22
21
15
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 6

Figure 7. Spectral transmittance of color transparencies of green and yellow leaves of trees on Ansco daylight color film.

(24) W-80 Yellow Leaves of Sycamore (Platanus occidentalis, L.)

(25) W-81 Close-up of Yellow Leaves of Sycamore

(26) W-121 Green Leaves of Sycamore (Platanus occidentalis, L.)

(27) W-122 Close-up of Green Leaves of Sycamore

(28) W-123 Green Leaves of Black Oak (Quercus velutina, Lam.)

(29) W-131 Close-up of Green Leaves of Black Oak

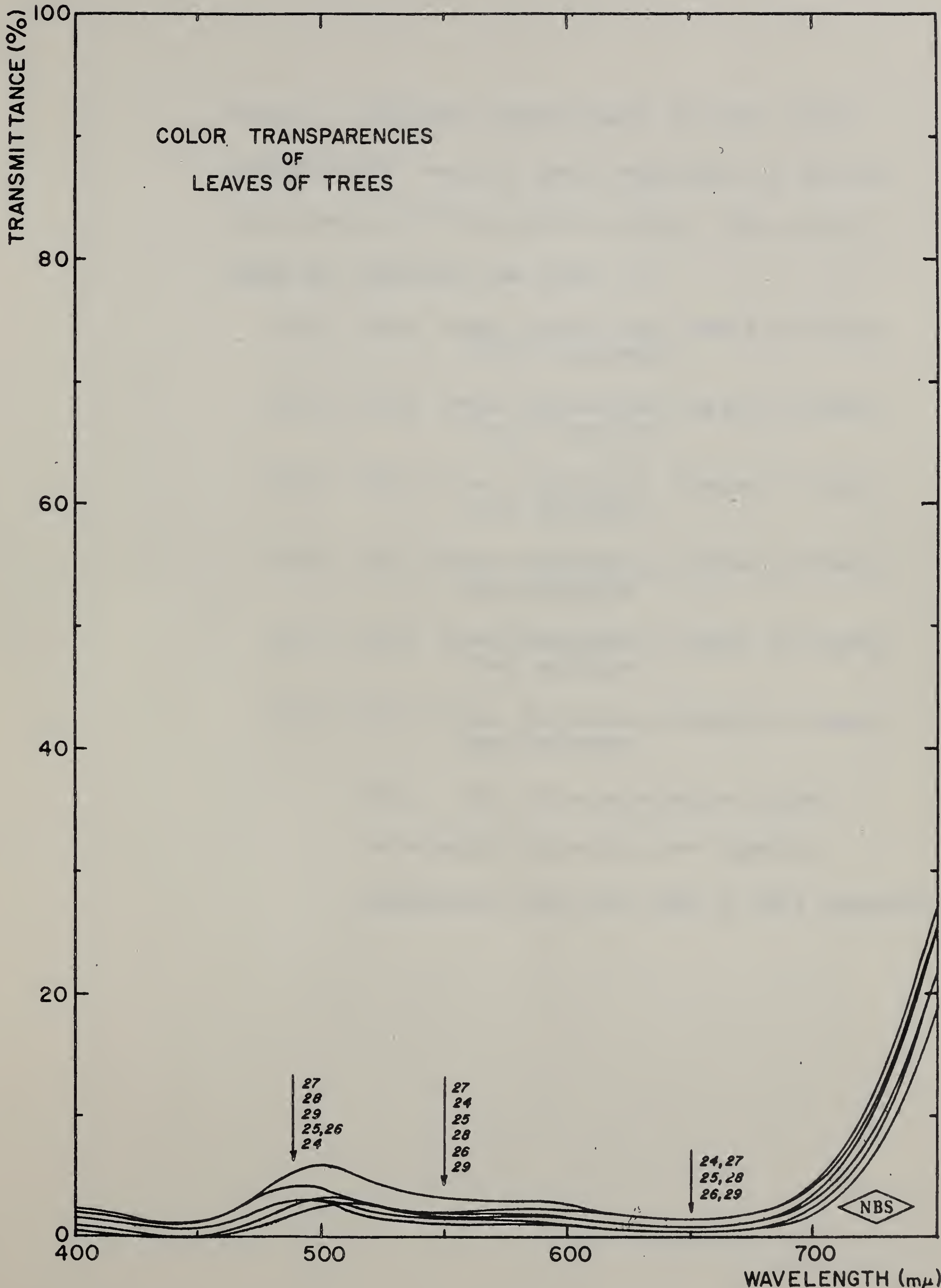

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
LEAVES OF TREES
27
28
29
25,26
24
27
24
25
28
26
29
24,27
25,28
26,29
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 7

Figure 8. Spectral transmittance of color transparencies of a scene of green vegetation on special Ansco green and blue sensitive film. (For shutter speed and aperture, see Table I).

(30) W-143 Green Vegetation, Leaves in Light, Normal exposure

(31) W-143 Green Vegetation, Leaves in Shade, Normal exposure

(32) W-144 Green Vegetation, Leaves in Light, Over exposure

(33) W-144 Green Vegetation, Leaves in Shade, Over exposure

(34) W-145 Green Vegetation, Leaves in Light, Over exposure

(35) W-145 Green Vegetation, Leaves in Shade, Over exposure

(Note. When the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

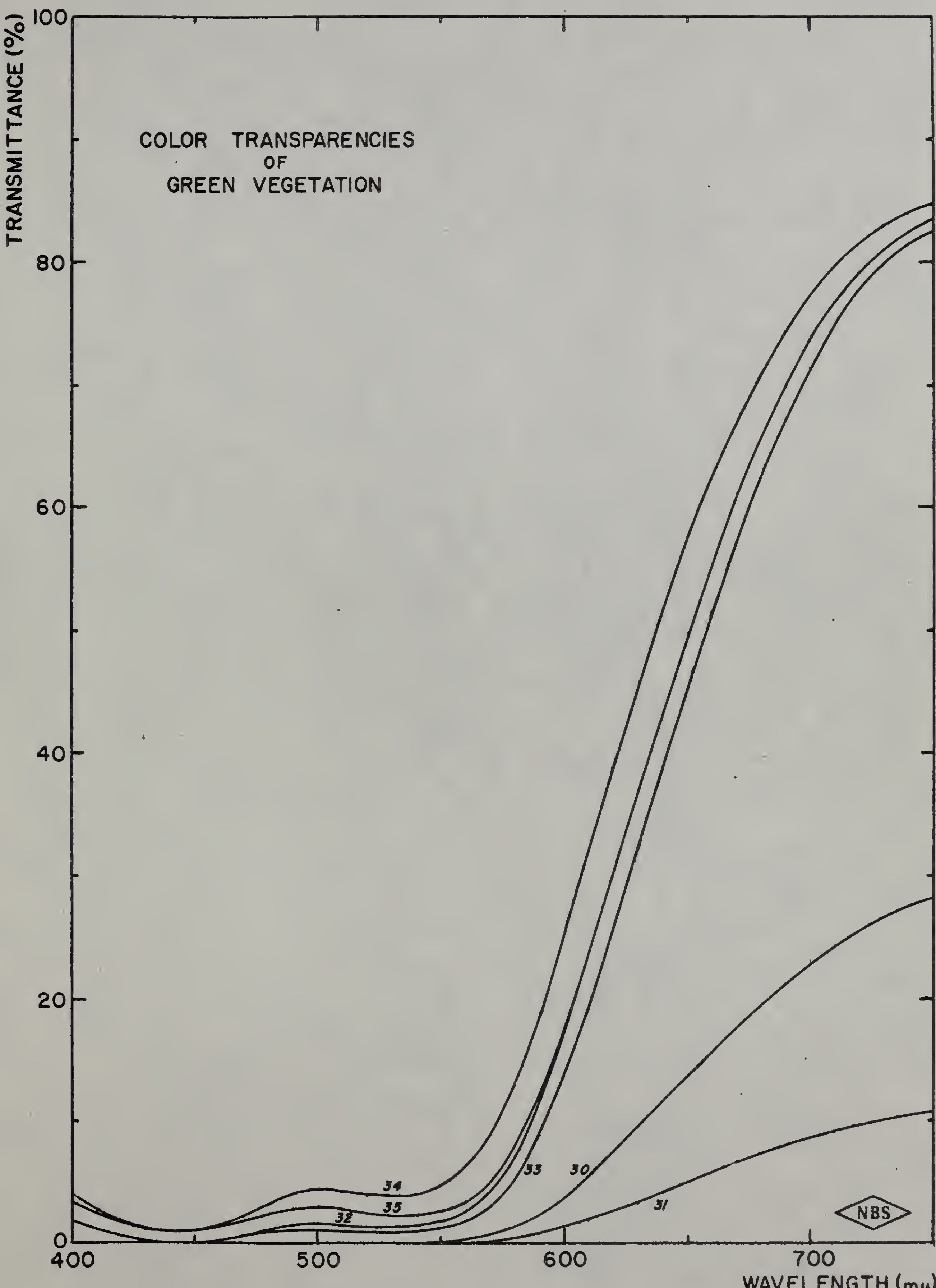

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
GREEN VEGETATION
34
35
32
33
30
31
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 8

Figure 9. Spectral transmittance of color transparencies of a scene of green leaves of a hedge of Black Walnut and of Locust trees on special Ansco blue and red sensitive film. (For shutter speed and aperture, see Table I).

(36) W-174 Green Hedge of Black Walnut and Locust, Leaves in Light, Under exposure

(37) W-174 Green Hedge of Black Walnut and Locust, Leaves in Shade, Under exposure

(38) W-175 Green Hedge of Black Walnut and Locust, Leaves in Light, Normal exposure

(39) W-175 Green Hedge of Black Walnut and Locust, Leaves in Shade, Normal exposure

(40) W-176 Green Hedge of Black Walnut and Locust, Leaves in Light, Over exposure

(41) W-176 Green Hedge of Black Walnut and Locust, Leaves in Shade, Over exposure

(Note. When the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

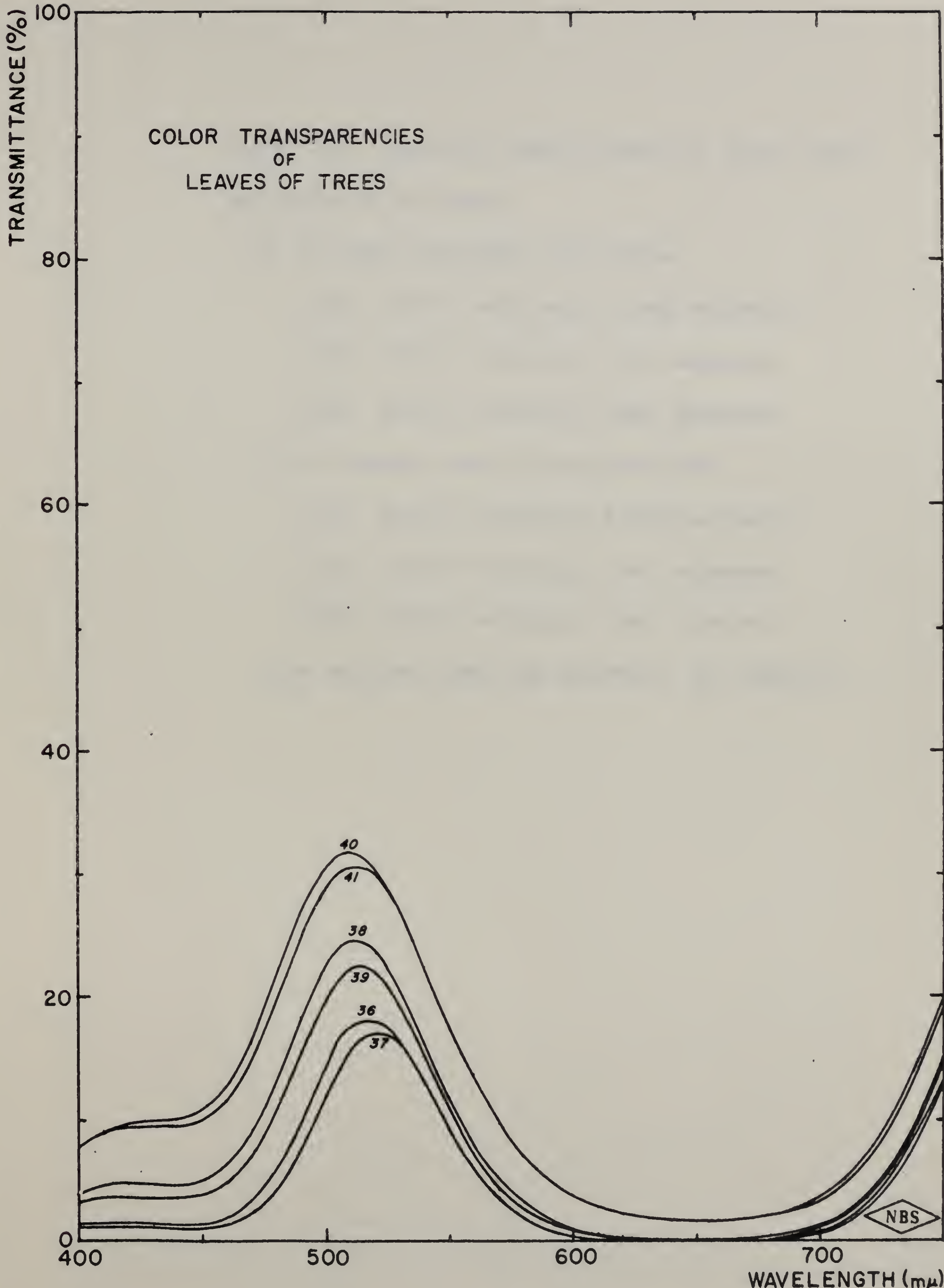

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
LEAVES OF TREES
40
41
38
39
36
37
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 9

Figure 10. Spectral transmittance of color transparencies of wet sand.

a) On Ansco Daylight Color Film

(42) W-872 Wet Sand, Normal exposure

(43) W-873 Wet Sand, Over exposure

(44) W-874 Wet Sand, Over exposure

b) On Special Ansco Plenacolor Film

(63) W-917 Wet Sand, Normal exposure

(64) W-918 Wet Sand, Over exposure

(65) W-919 Wet Sand, Over exposure

(For shutter speed and aperture, see Table I).

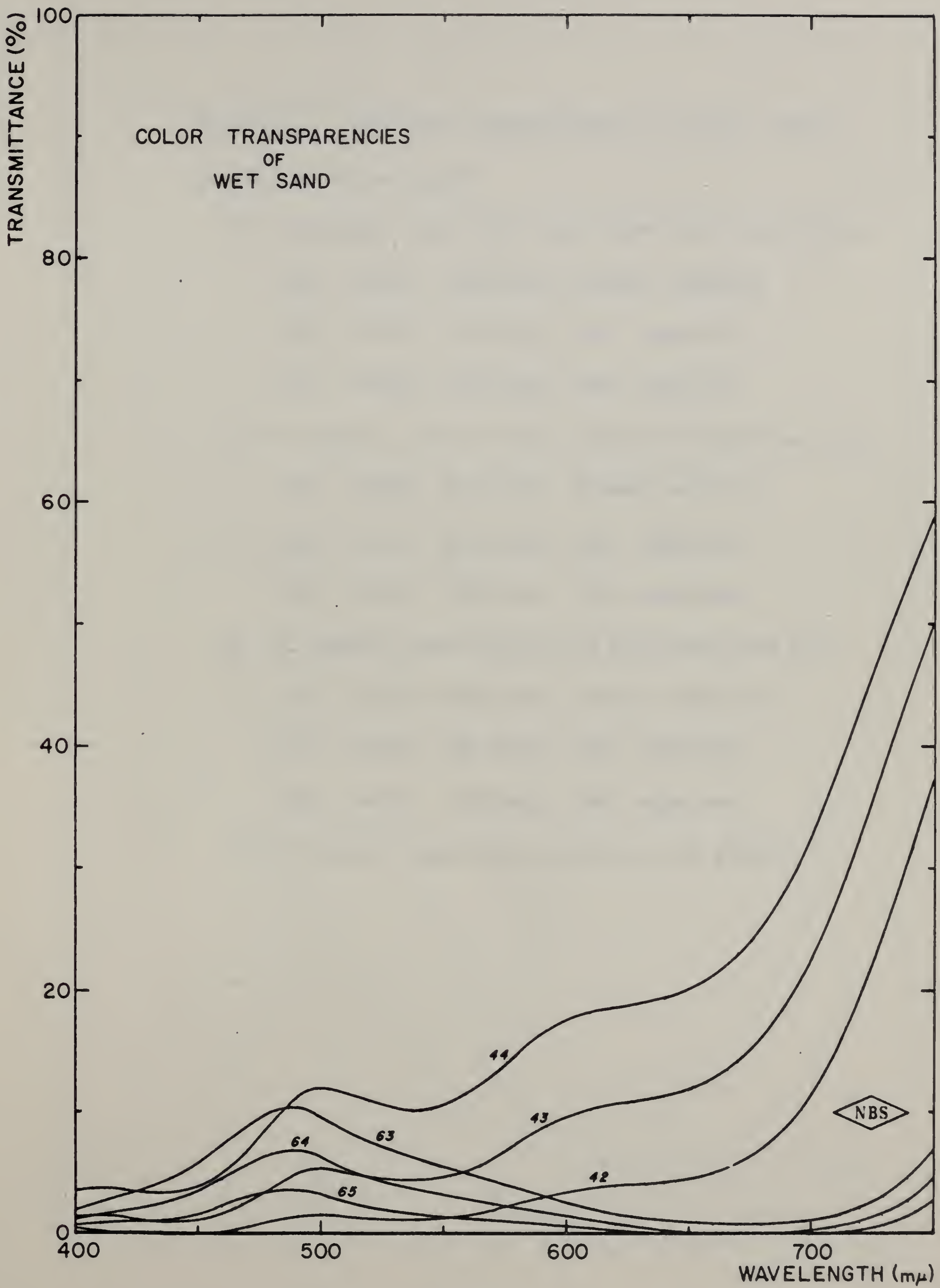

TRANSMITTANCE (%)
100
80
60
40
20
0
400
500
600
700
WAVELENGTH (mμ)
COLOR TRANSPARENCIES
OF
WET SAND
44
43
42
63
64
65
NBS

FIGURE 10

Figure 11. Spectral transmittance of color transparencies of wet sand.

a) On Special Ansco Red and Green Sensitive Film

(45) W-890 Wet Sand, Normal exposure

(46) W-891 Wet Sand, Over exposure

(47) W-892 Wet Sand, Over exposure

b) On Special Ansco Green and Blue Sensitive Film

(48) W-899 Wet Sand, Normal exposure

(49) W-900 Wet Sand, Over exposure

(50) W-901 Wet Sand, Over exposure

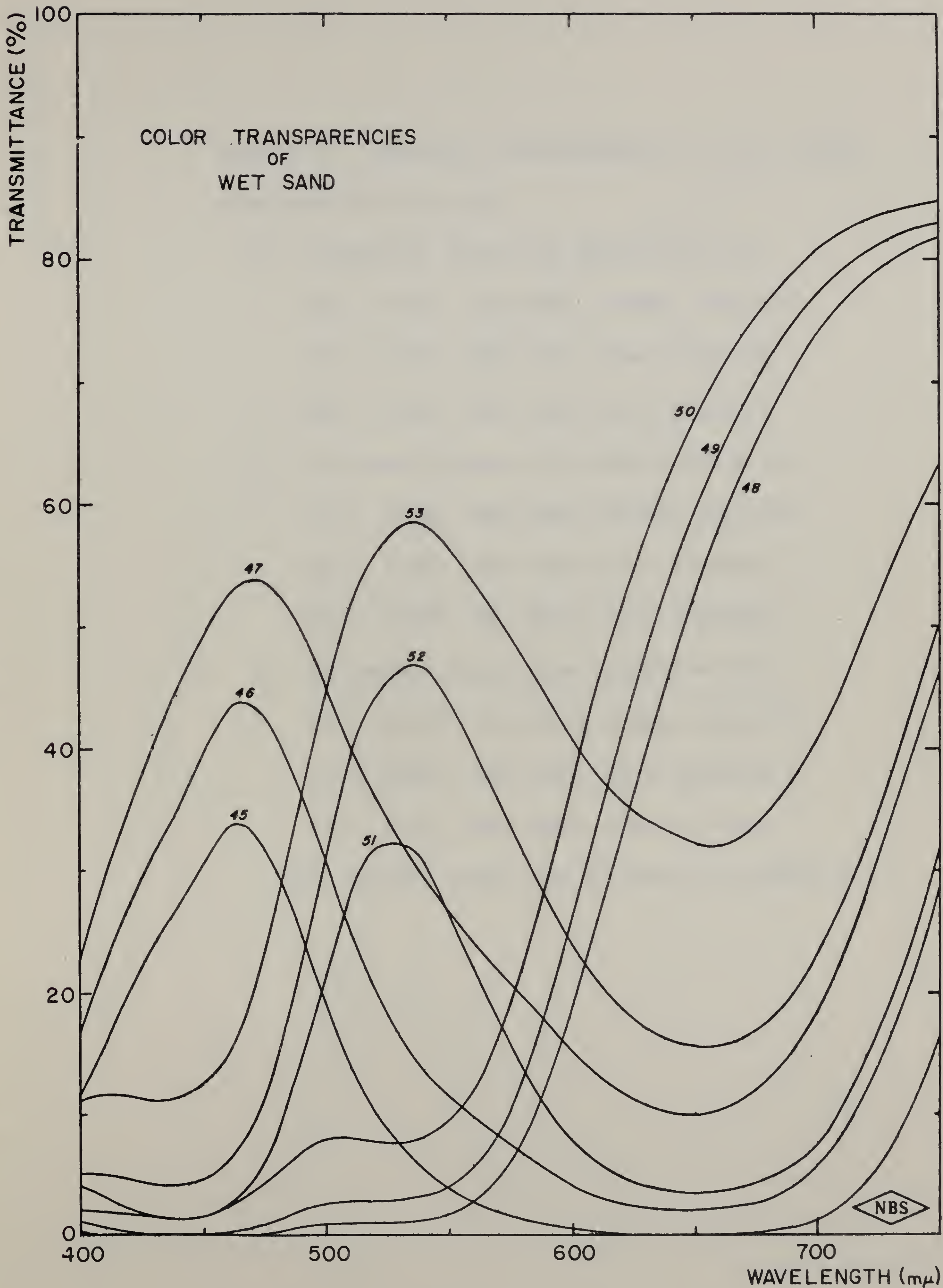
c) On Special Ansco Blue and Red Sensitive Film

(51) W-881 Wet Sand, Normal exposure

(52) W-882 Wet Sand, Over exposure

(53) W-883 Wet Sand, Over exposure

(For shutter speed and aperture, see Table I).



TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
WET SAND
50
49
48
53
47
52
46
45
51
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 11

Figure 12. Spectral transmittance of color transparencies of wet sand.

a) On Special Ansco Red Sensitive Film

(54) W-935 Wet Sand, Normal exposure

(55) W-936 Wet Sand, Over exposure

(56) W-937 Wet Sand, Over exposure

b) On Special Ansco Green Sensitive Film

(57) W-926 Wet Sand, Normal exposure

(58) W-927 Wet Sand, Over exposure

(59) W-928 Wet Sand, Over exposure

c) On Special Ansco Blue Sensitive Film

(60) W-908 Wet Sand, Normal exposure

(61) W-909 Wet Sand, Over exposure

(62) W-910 Wet Sand, Over exposure

(For shutter speed and aperture, see Table I).

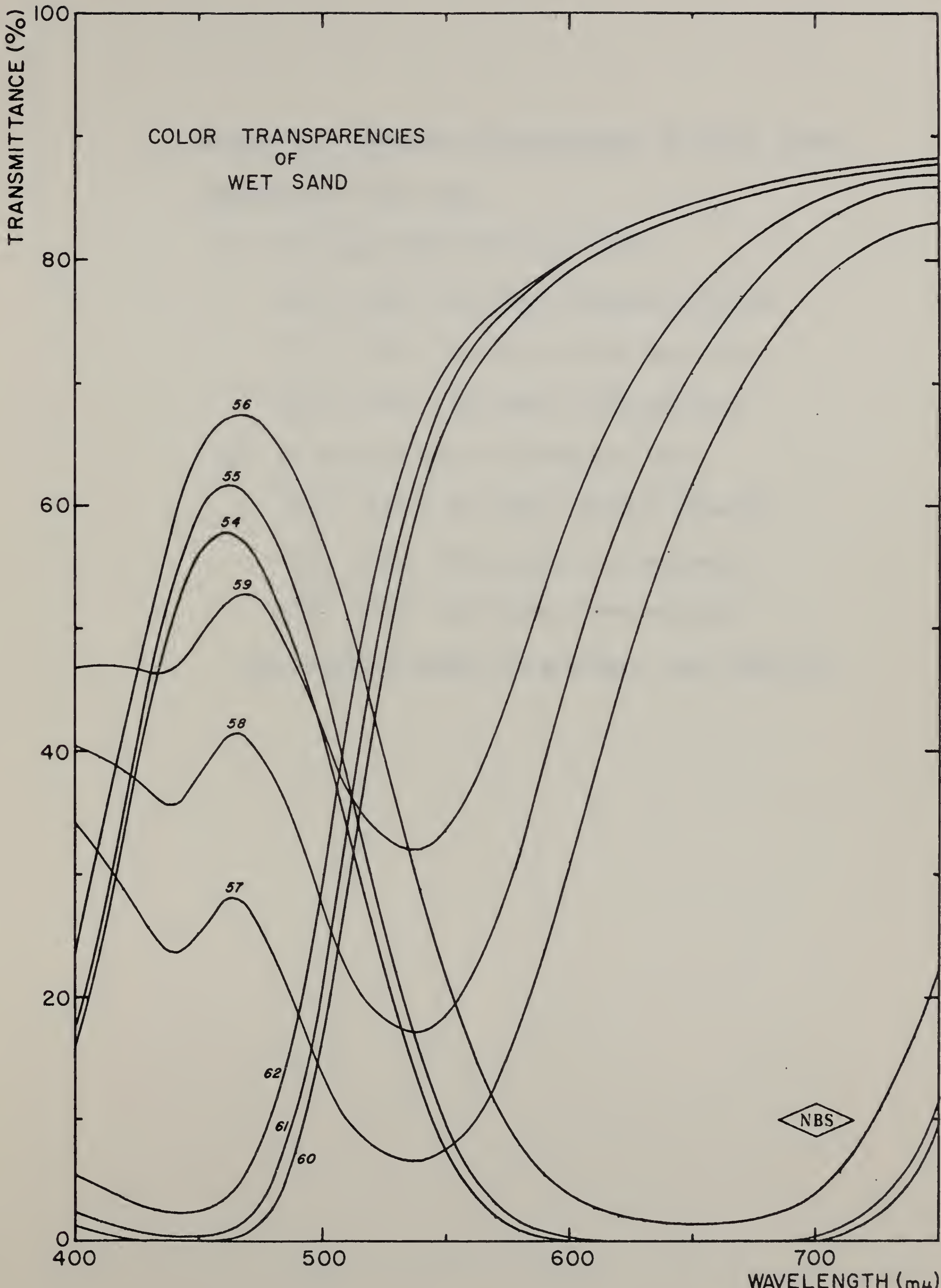

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
WET SAND
56
55
54
59
58
57
62
61
60
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 12

Figure 13. Spectral transmittance of color transparencies of dry sand.

a) On Ansco Daylight Color Film

(66) W-875 Dry Sand, Normal exposure

(67) W-876 Dry Sand, Over exposure

(68) W-877 Dry Sand, Over exposure

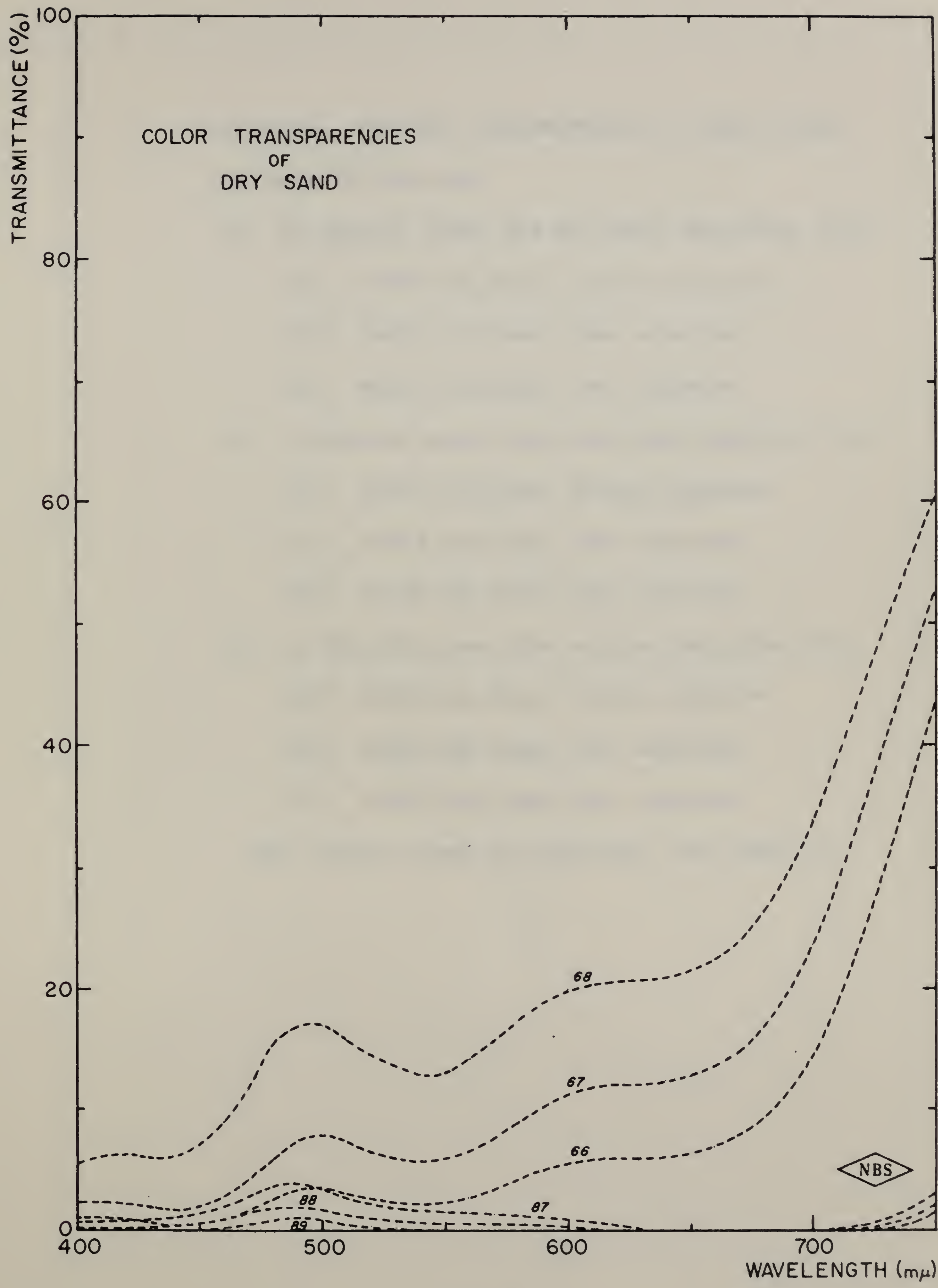
b) On Special Ansco Plenacolor Film

(87) W-920 Dry Sand, Normal exposure

(88) W-921 Dry Sand, Over exposure

(89) W-922 Dry Sand, Over exposure

(For shutter speed and aperture, see Table I).



TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
DRY SAND
68
67
66
88
87
89
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 13

Figure 14. Spectral transmittance of color transparencies of dry sand.

a) On Special Ansco Red and Green Sensitive Film

(69) W-893 Dry Sand, Normal exposure

(70) W-894 Dry Sand, Over exposure

(71) W-895 Dry Sand, Over exposure

b) On Special Ansco Green and Blue Sensitive Film

(72) W-902 Dry Sand, Normal exposure

(73) W-903 Dry Sand, Over exposure

(74) W-904 Dry Sand, Over exposure

c) On Special Ansco Blue and Red Sensitive Film

(75) W-884 Dry Sand, Normal exposure

(76) W-885 Dry Sand, Over exposure

(77) W-886 Dry Sand, Over exposure

(For shutter speed and aperture, see Table I).

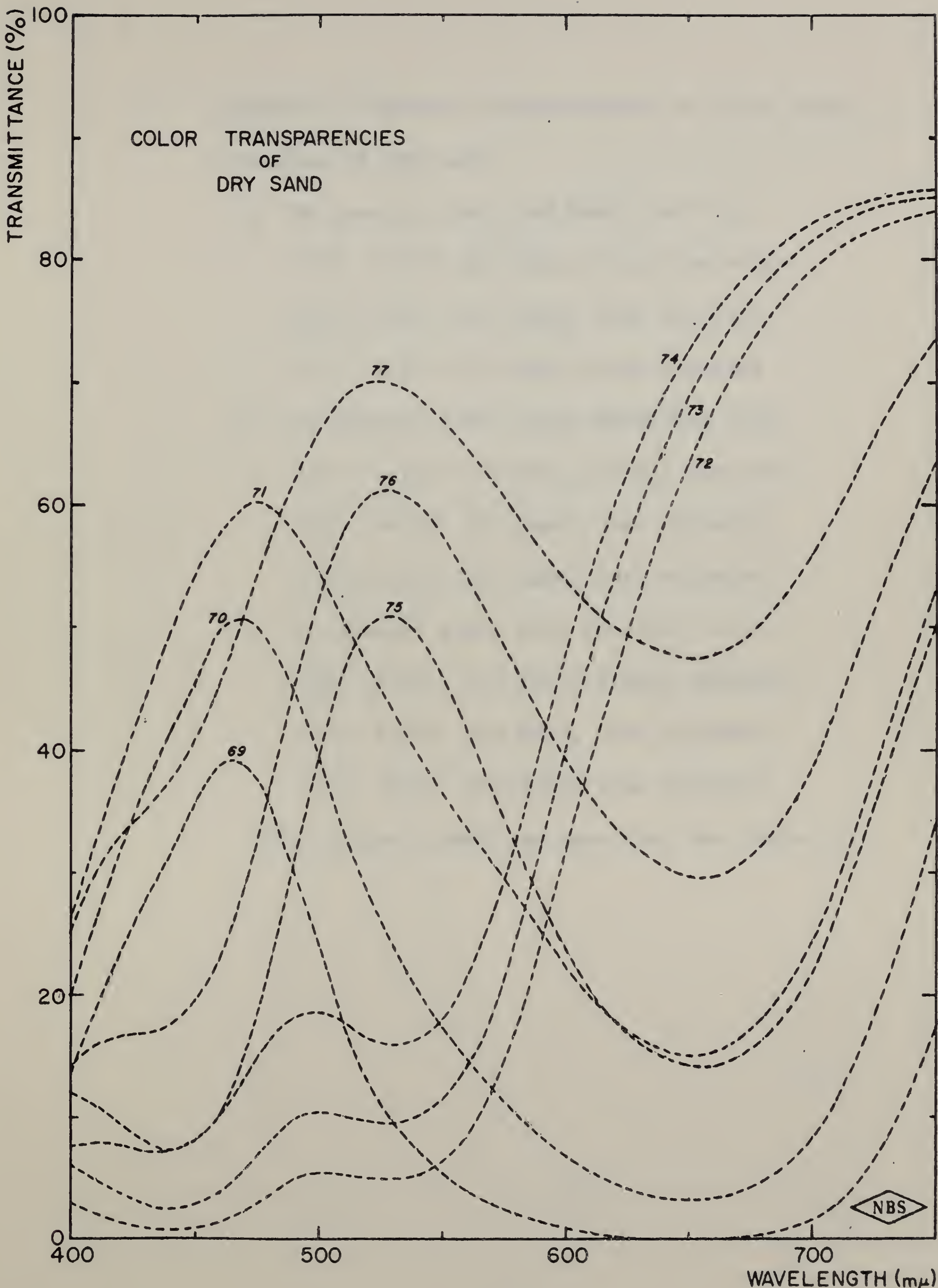

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
DRY SAND
77
71
76
70
75
69
74
73
72
400
500
600
700
WAVELENGTH (mμ)
NBS

FIGURE 14

Figure 15. Spectral transmittance of color transparencies of dry sand.

a) On Special Ansco Red Sensitive Film

(78) W-938 Dry Sand, Normal exposure

(79) W-939 Dry Sand, Over exposure

(80) W-940 Dry Sand, Over exposure

b) On Special Ansco Green Sensitive Film

(81) W-929 Dry Sand, Normal exposure

(82) W-930 Dry Sand, Over exposure

(83) W-931 Dry Sand, Over exposure

c) On Special Ansco Blue Sensitive Film

(84) W-911 Dry Sand, Normal exposure

(85) W-912 Dry Sand, Over exposure

(86) W-913 Dry Sand, Over exposure

(For shutter speed and aperture, see Table I).

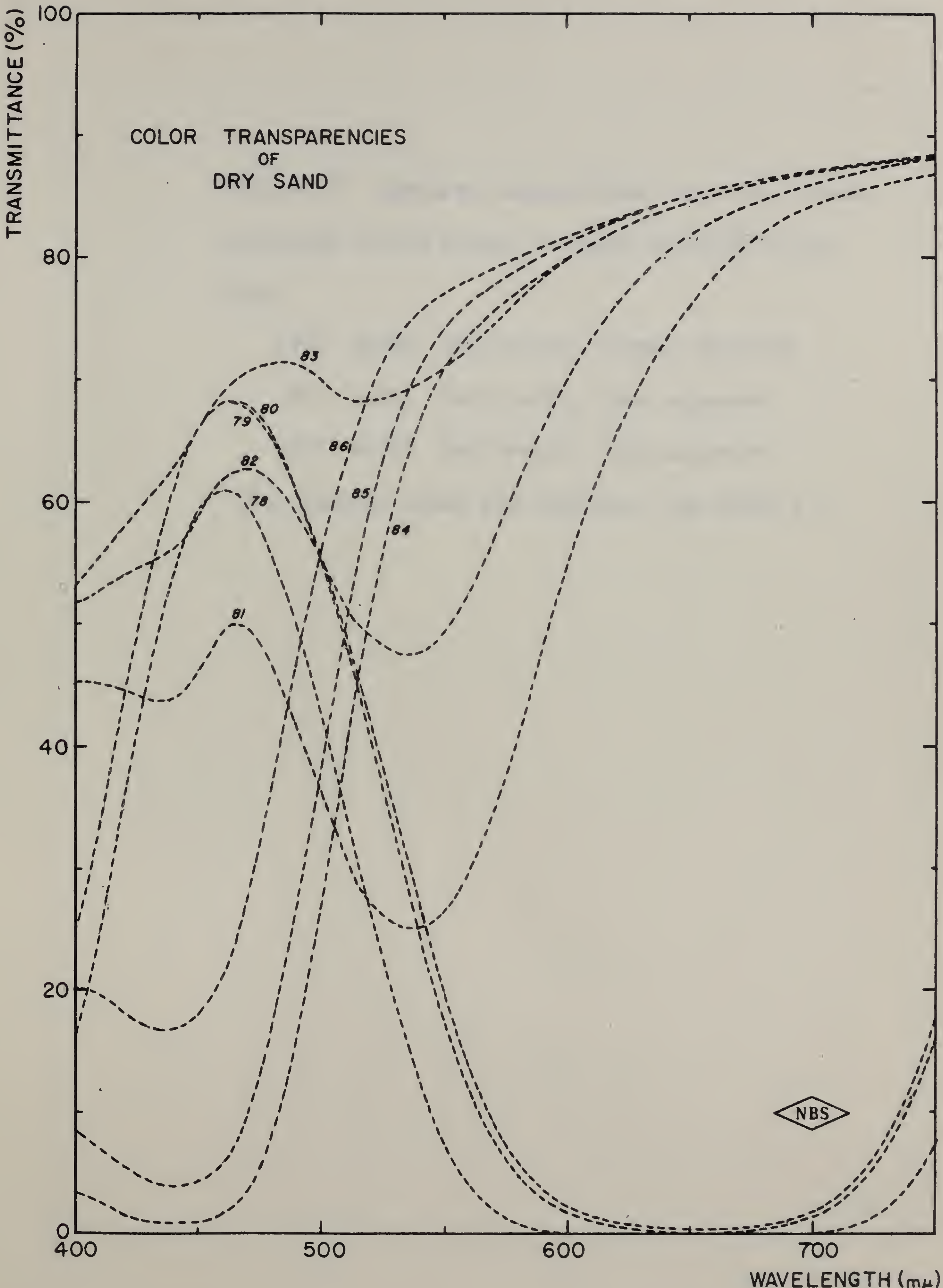

COLOR TRANSPARENCIES
OF
DRY SAND
TRANSMITTANCE (%)
WAVELENGTH (mμ)
100
80
60
40
20
0
400
500
600
700
83
80
79
86
82
85
78
84
81
NBS

FIGURE 15

Figure 16. Spectral transmittance of color transparencies of wet gravel on Ansco daylight color film.

(90) W-944 Wet Gravel, Normal exposure

(91) W-945 Wet Gravel, Over exposure

(92) W-946 Wet Gravel, Over exposure

(For shutter speed and aperture, see Table I).

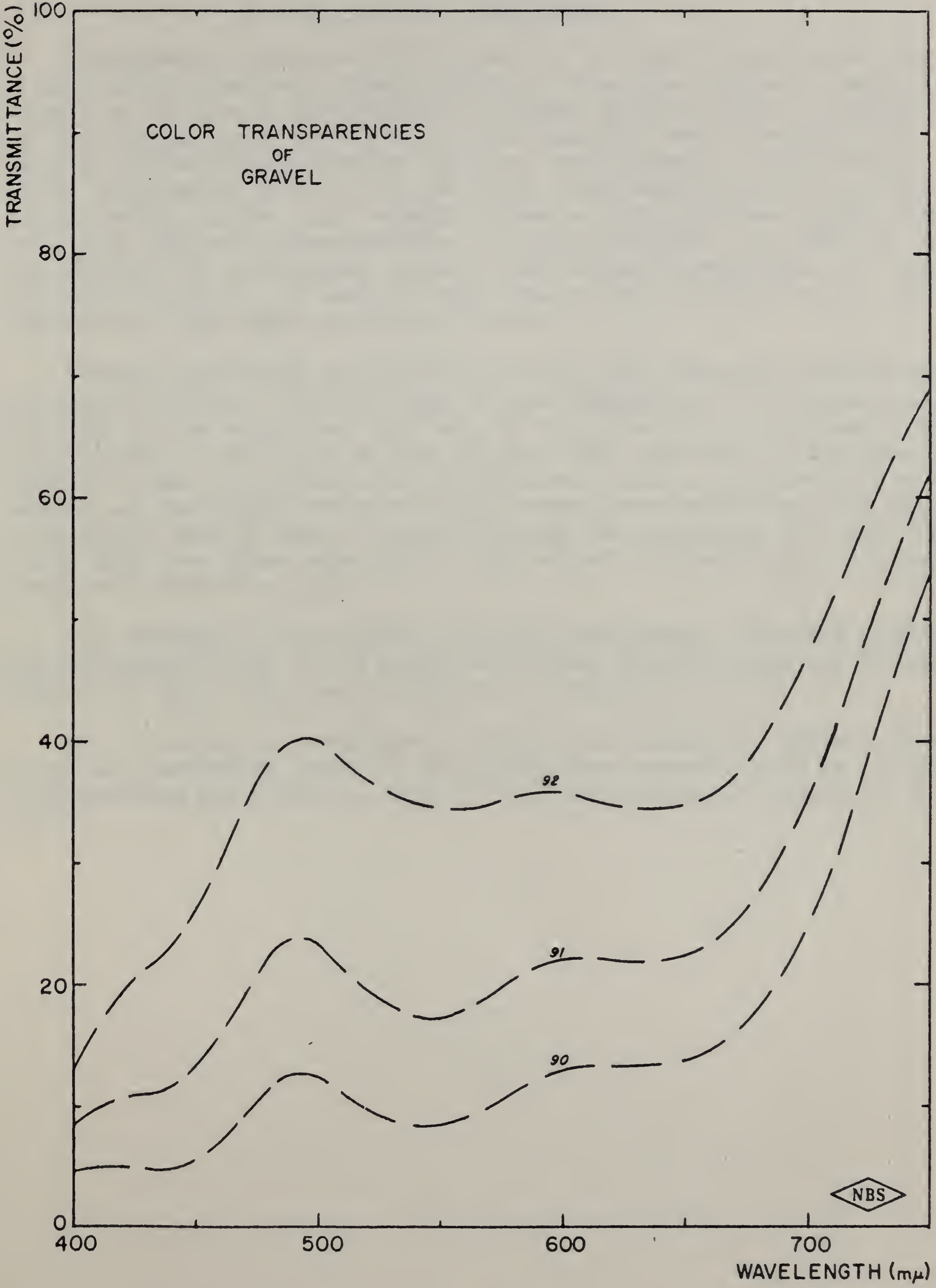

TRANSMITTANCE (%)
100
80
60
40
20
0
COLOR TRANSPARENCIES
OF
GRAVEL
92
91
90
NBS
400
500
600
700
WAVELENGTH (mμ)

FIGURE 16

VI. Colorimetric Computations

The spectral-directional-reflectance or spectral-transmittance data of each of the ninety-six determinations of specimens related to natural objects or to color transparencies of natural objects listed in Appendix B for the visible spectrum (400 to 750 millimicrons) were converted into terms of luminous reflectance or luminous transmittance, Y, and chromaticity coordinates, x and y, of the C.I.E. colorimetric system by integration according to the C.I.E. standard observer and coordinate system [14] for C.I.E. source C, representative of average daylight. In addition to the chromaticity coordinates, x and y, the dominant wavelength, λ , and excitation purity, p, of each of these ninety-six determinations of the specimens of this report have been derived.

Dominant wavelength and excitation purity are alternate standard specifications for color. They are more or less suggestive of the appearance of the color of the object and thus help to form a part of the chromaticity specification of the color of that object. This sometimes is more easily understood than the chromaticity coordinates, x and y. The dominant wavelengths and excitation purities of this report were determined from the chromaticity data by means of graphs showing the conversion of C.I.E. chromaticity data into these terms [15]. This method is recognized by the American Standards Association [16].

The chromaticity coordinates, daylight reflectance, dominant wavelength, and excitation purity of the eleven reflecting determinations are listed in Table II of this report and illustrated in Figures 17 and 18.

The chromaticity coordinates, daylight transmittance, dominant wavelength and excitation purity of the eighty-five determinations on the color transparencies are listed in Table III and illustrated in Figures 19, 20, and 21.

Table II

Reflecting Natural Objects

Chromaticity Coordinates, Daylight Reflectance, Dominant Wavelength, and Excitation Purity, for Source C, of the Indicated Samples.

Sample Number	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)	Dominant Wavelength Λ(mμ)	Excitation Purity p(%)
			Sand and Soil		
(1)	0.359	0.356	21.8	580.4	23.7
(2)	.392	.373	21.0	582.7	37.2
(3)	.354	.348	16.5	582.0	20.3
(4)	.350	.349	37.7	580.3	19.5
(5)	.373	.363	36.9	581.6	29.4
(6)	.337	.337	27.7	580.0	13.0
(7)	.349	.345	14.9	582.0	18.0
			Barks of Trees		
(93)	.358	.346	11.9	584.2	20.8
(94)	.372	.349	14.7	586.4	25.4
(95)	.326	.342	27.7	571.1	11.1
(96)	.357	.350	7.5	580.2	23.1

Figure 17. CIE chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of wet sands (solid circles), dry sands (open circles), and damp soil.

(1) Wet White Sand, Rodger's Quarry

(2) Wet Yellowish Quartz Sand, Rodger's Quarry

(3) Wet Commercial (Zonalite) "Vermiculite"

(4) Dry White Sand, Rodger's Quarry

(5) Dry Yellowish Quartz Sand, Rodger's Quarry

(6) Dry Commercial (Zonalite) "Vermiculite"

(7) Damp Collington Sandy Loam

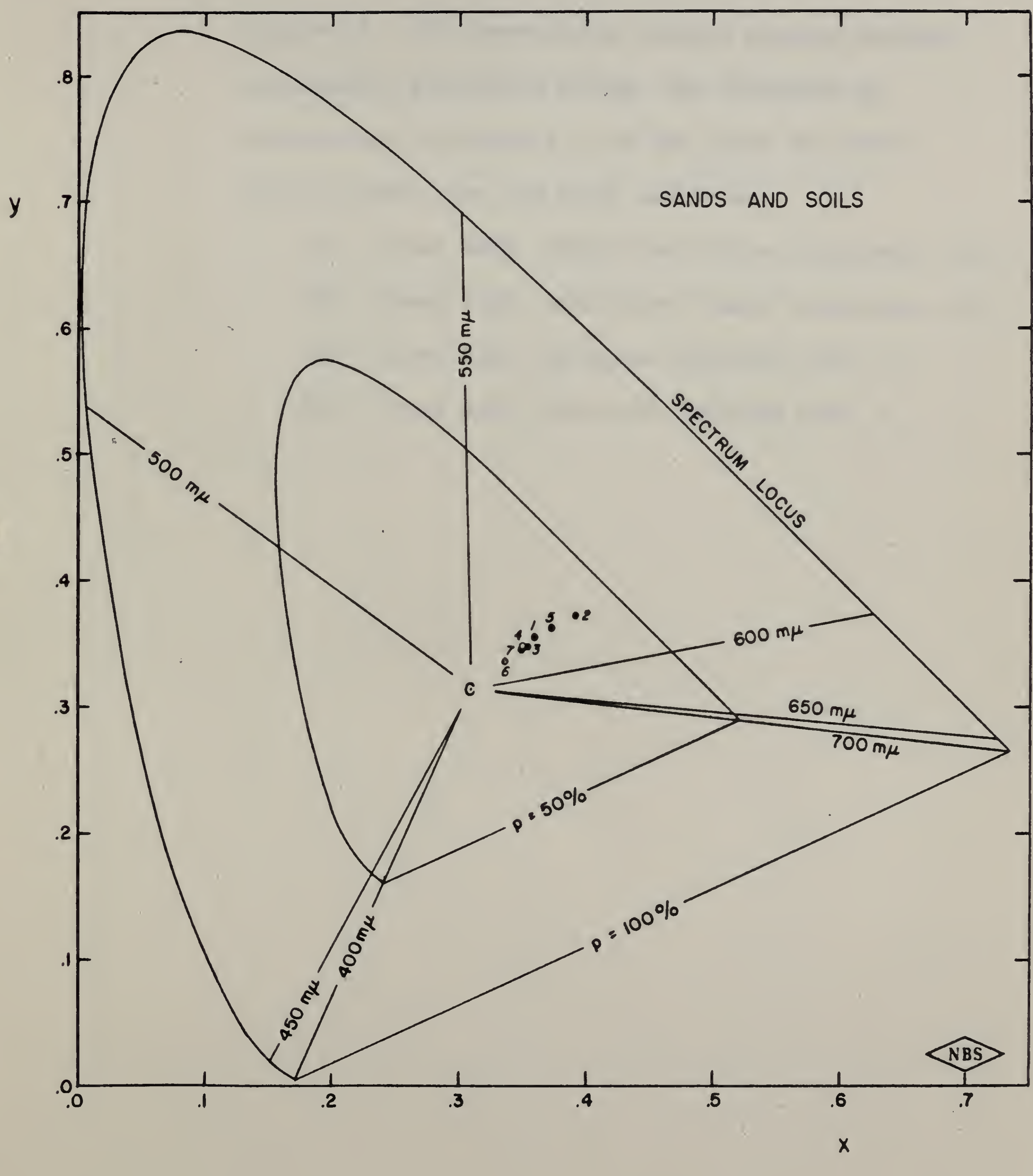

SANDS AND SOILS
SPECTRUM LOCUS
550 mμ
500 mμ
600 mμ
650 mμ
700 mμ
450 mμ
400 mμ
p = 50%
p = 100%
C
1
2
3
4
5
6
7
y
x
.0
.1
.2
.3
.4
.5
.6
.7
.8
NBS

FIGURE 17

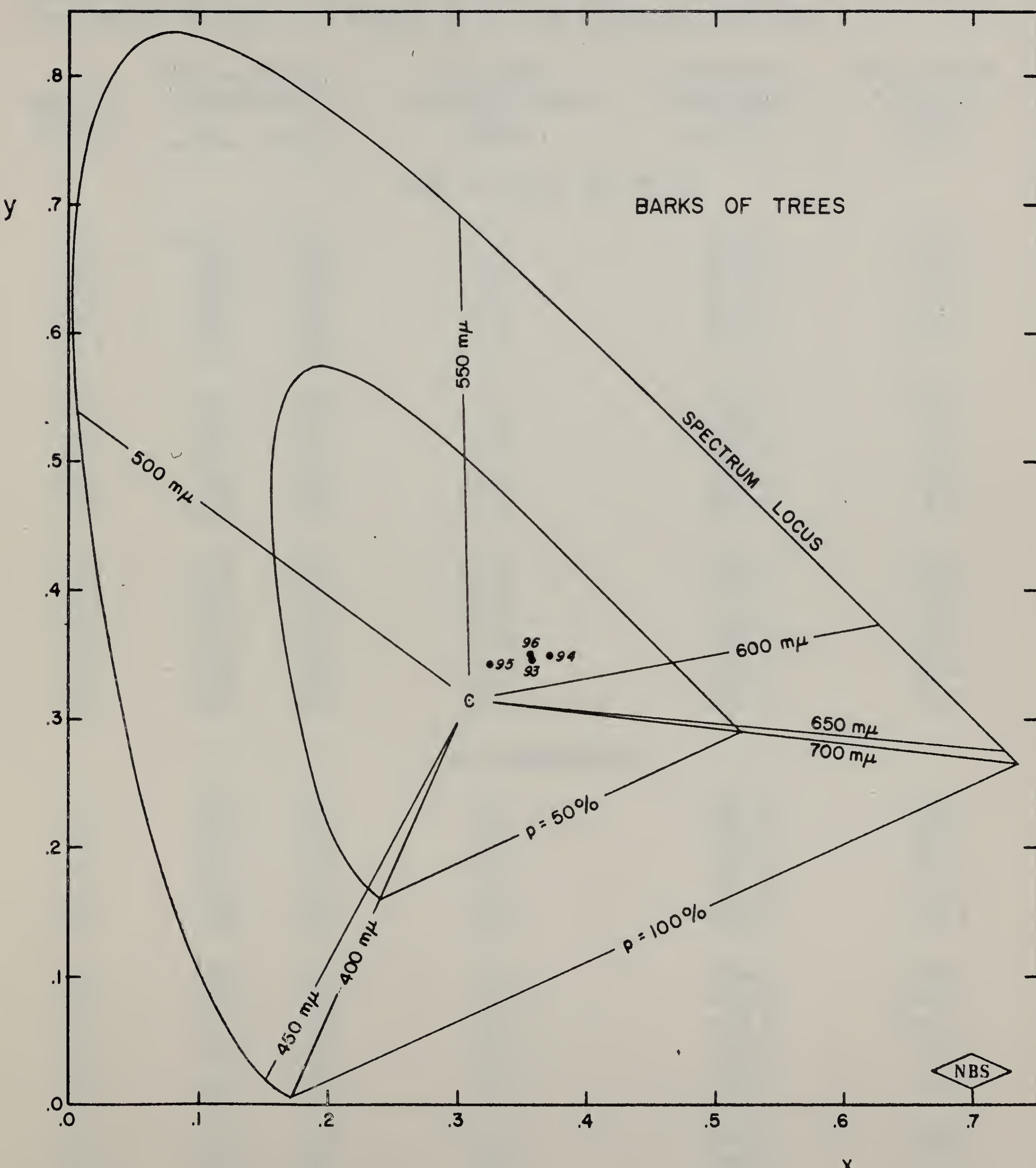
Figure 18. CIE chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of the inner and outer bark of scrub pine and white oak trees.

(93) Outer Bark, Scrub Pine (Pinus virginiana, Mill.)

(94) Inner Bark, Scrub Pine (Pinus virginiana, Mill.)

(95) Outer Bark, White Oak (Quercus alba, L.)

(96) Inner Bark, White Oak (Quercus alba, L.)



BARKS OF TREES
y
.8
.7
.6
.5
.4
.3
.2
.1
.0
.0
.1
.2
.3
.4
.5
.6
.7
x
SPECTRUM LOCUS
550 mμ
500 mμ
600 mμ
650 mμ
700 mμ
450 mμ
400 mμ
p = 50%
p = 100%
C
96
95
94
93
NBS

FIGURE 18

Table III

Color Transparencies of Natural Objects

Chromaticity Coordinates, Daylight Transmittance, Dominant Wavelength, and Excitation Purity, for Source C, of the Indicated Samples.

Sample Number	Chromaticity Coordinates x	y	Daylight Transmittance Y(%)	Dominant Wavelength Λ(mμ)	Excitation Purity p(%)
			Sky, Clouds, and Water		
(8)	0.207	0.197	2.6	474.8	51.7
(9)	.254	.248	6.4	473.6	28.7
(10)	.298	.322	54.6	497.0	4.0
(11)	.257	.253	5.9	474.3	26.9
(12)	.224	.232	1.5	477.9	41.0
(13)	.220	.248	1.1	481.2	40.2
(14)	.297	.313	3.6	488.0	5.1
(15)	.316	.323	7.7	575.6	3.4
(16)	.293	.320	33.6	493.1	7.2
(17)	.298	.328	49.4	502.9	4.0
(18)	.157	.304	13.1	490.0	57.9
(19)	.234	.311	41.4	490.2	28.8
(20)	.275	.319	59.9	491.9	12.9
(21)	.146	.362	8.2	494.3	57.8
(22)	.146	.208	13.6	482.6	71.4
(23)	.175	.245	25.5	484.4	56.9
			Green Vegetation		
(24)	.389	.507	2.2	566.4	73.4
(25)	.319	.474	2.0	544.0	45.1
(26)	.278	.464	1.5	537.5	32.8
(27)	.285	.398	3.4	531.0	16.8
(28)	.260	.337	2.0	496.0	17.3
(29)	.242	.335	1.3	494.3	24.0
(30)	.670	.330	1.7	611.4	100.0
(31)	.682	.318	0.5	615.8	100.0
(32)	.627	.350	8.1	604.8	94.0
(33)	.637	.340	6.5	608.7	94.0
(34)	.575	.363	12.5	600.0	83.6
(35)	.585	.344	8.8	605.2	81.0
(36)	.179	.540	7.3	513.3	46.7
(37)	.192	.570	7.1	519.4	49.1
(38)	.177	.435	10.3	501.1	43.6

Table III (Continued)

Sample Number	Chromaticity Coordinates x	y	Daylight Transmittance Y(%)	Dominant Wavelength Λ(mμ)	Excitation Purity p(%)
			Green Vegetation (Continued)		
(39)	0.175	0.461	9.3	504.6	44.1
(40)	.199	.384	15.3	498.4	37.3
(41)	.203	.395	15.1	500.0	35.4
			Wet Sand		
(42)	.500	.420	2.0	586.0	78.8
(43)	.449	.405	6.4	583.8	61.1
(44)	.410	.396	13.0	580.7	48.1
(45)	.146	.132	6.0	475.4	81.3
(46)	.173	.189	13.0	478.7	64.2
(47)	.218	.252	26.5	482.1	40.4
(48)	.640	.355	8.5	603.9	98.8
(49)	.610	.373	12.1	599.6	95.4
(50)	.549	.384	19.0	594.6	82.1
(51)	.291	.559	19.3	546.8	61.2
(52)	.342	.509	34.2	558.5	60.5
(53)	.350	.455	48.1	562.8	48.0
(54)	.139	.146	12.2	477.6	81.6
(55)	.141	.156	14.1	478.4	79.7
(56)	.162	.206	23.1	481.9	65.8
(57)	.374	.236	17.7	507.1c	44.3
(58)	.354	.263	30.3	506.7c	29.7
(59)	.341	.287	44.2	502.9c	17.6
(60)	.486	.495	60.7	577.4	95.1
(61)	.477	.493	63.0	576.8	92.2
(62)	.458	.486	65.7	575.7	85.2
(63)	.219	.316	5.2	490.9	33.9
(64)	.206	.312	3.0	490.5	39.1
(65)	.190	.300	1.4	489.3	45.9
			Dry Sand		
(66)	.446	.402	3.5	584.0	59.6
(67)	.418	.395	7.8	582.0	50.1
(68)	.374	.373	15.9	579.4	32.3
(69)	.149	.140	7.7	475.9	79.1
(70)	.184	.213	18.3	480.3	57.3

Table III (Continued)

Sample Number	Chromaticity Coordinates x	y	Daylight Transmittance Y(%)	Dominant Wavelength λ(mμ)	Excitation Purity p(%)
			Dry Sand (Continued)		
(71)	0.235	0.277	35.3	484.5	31.6
(72)	.573	.375	15.4	597.4	86.2
(73)	.525	.380	21.4	594.0	74.6
(74)	.468	.369	28.5	592.6	56.4
(75)	.316	.483	36.7	553.0	46.8
(76)	.323	.426	49.7	556.6	33.1
(77)	.314	.371	61.9	554.8	15.8
(78)	.139	.144	12.6	477.4	82.0
(79)	.151	.188	20.5	480.5	72.0
(80)	.155	.194	21.6	480.8	69.8
(81)	.345	.274	38.7	506.7c	23.5
(82)	.334	.304	57.8	497.3c	9.6
(83)	.328	.326	73.8	586.0	7.5
(84)	.466	.492	64.9	575.9	88.9
(85)	.443	.479	69.0	574.8	79.4
(86)	.397	.433	73.7	573.7	54.9
(87)	.207	.320	1.5	491.4	38.0
(88)	.186	.312	0.6	490.6	46.4
(89)	.093	.243	0.1	486.8	86.9
			Wet Gravel		
(90)	.358	.356	10.5	580.1	23.5
(91)	.336	.347	19.8	575.1	15.2
(92)	.322	.348	35.6	565.3	11.7

Figure 19. CIE chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of color transparencies of sky, clouds, water, and seaweed.

a) On Ansco Daylight Color Film

(8) W-68	(13) W-73
(9) W-69	(14) W-73
(10) W-70	(15) W-300
(11) W-71	(16) W-301
(12) W-72	(17) W-302

b) On Special Ansco Blue and Red Sensitive Film

(18) W-177	(21) W-180
(19) W-178	(22) W-181
(20) W-179	(23) W-182

(For identification of samples, shutter speed, and aperture, see Table I. Note, when the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

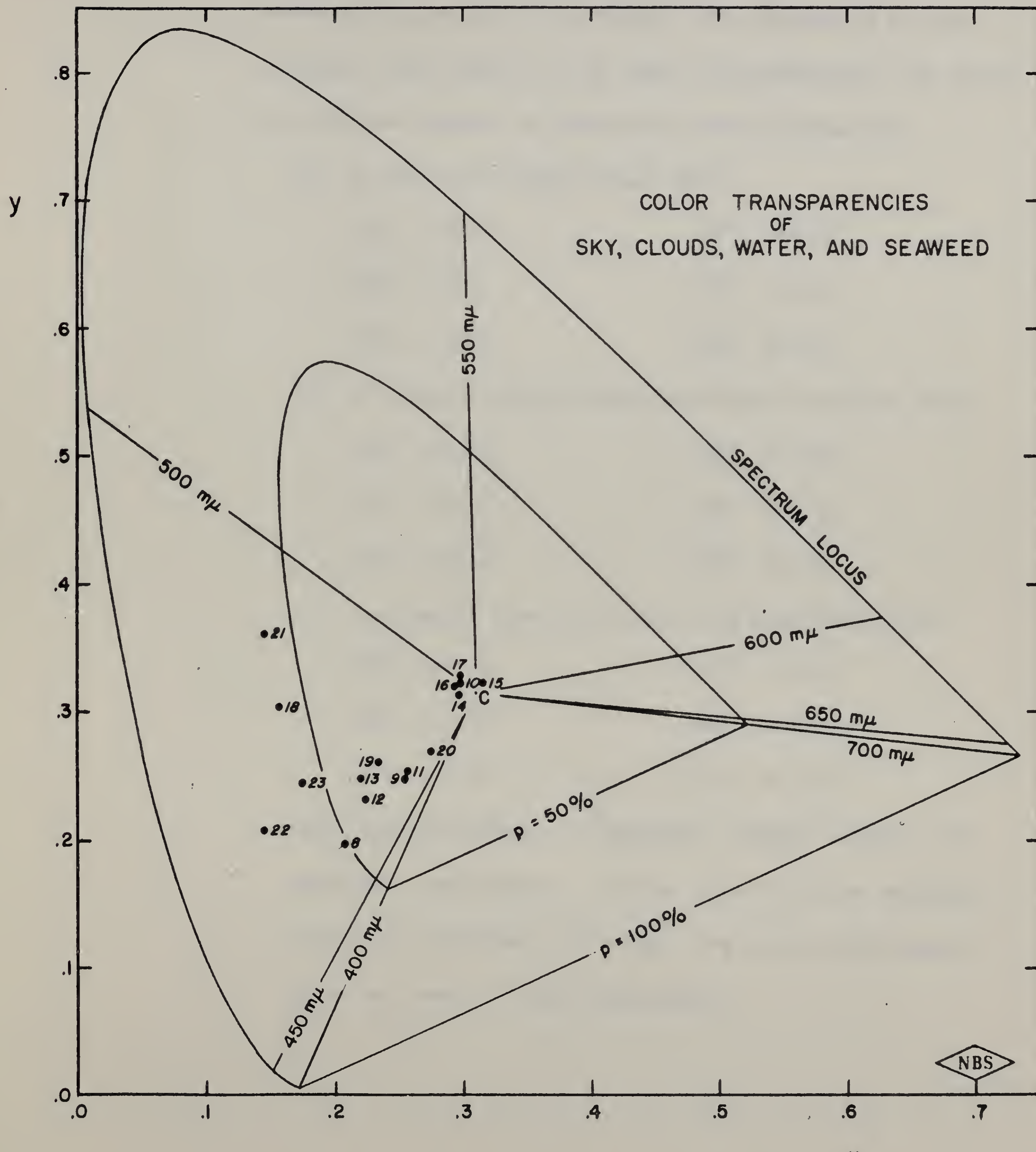

COLOR TRANSPARENCIES
OF
SKY, CLOUDS, WATER, AND SEAWEED
SPECTRUM LOCUS
550 mμ
500 mμ
600 mμ
650 mμ
700 mμ
450 mμ
400 mμ
p = 50%
p = 100%
C
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
NBS
y
x
.0
.1
.2
.3
.4
.5
.6
.7
.8

FIGURE 19

Figure 20. CIE chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of color transparencies of green and yellow leaves of trees and green vegetation.

a) On Ansco Daylight Color Film

(24) W-80	(27) W-122
(25) W-81	(28) W-123
(26) W-121	(29) W-131

b) On Special Ansco Green and Blue Sensitive Film

(30) W-143	(33) W-144
(31) W-143	(34) W-145
(32) W-144	(35) W-145

c) On Special Ansco Blue and Red Sensitive Film

(36) W-174	(39) W-175
(37) W-174	(40) W-176
(38) W-175	(41) W-176

(For identification of samples, shutter speed, and aperture, see Table I. Note, when the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

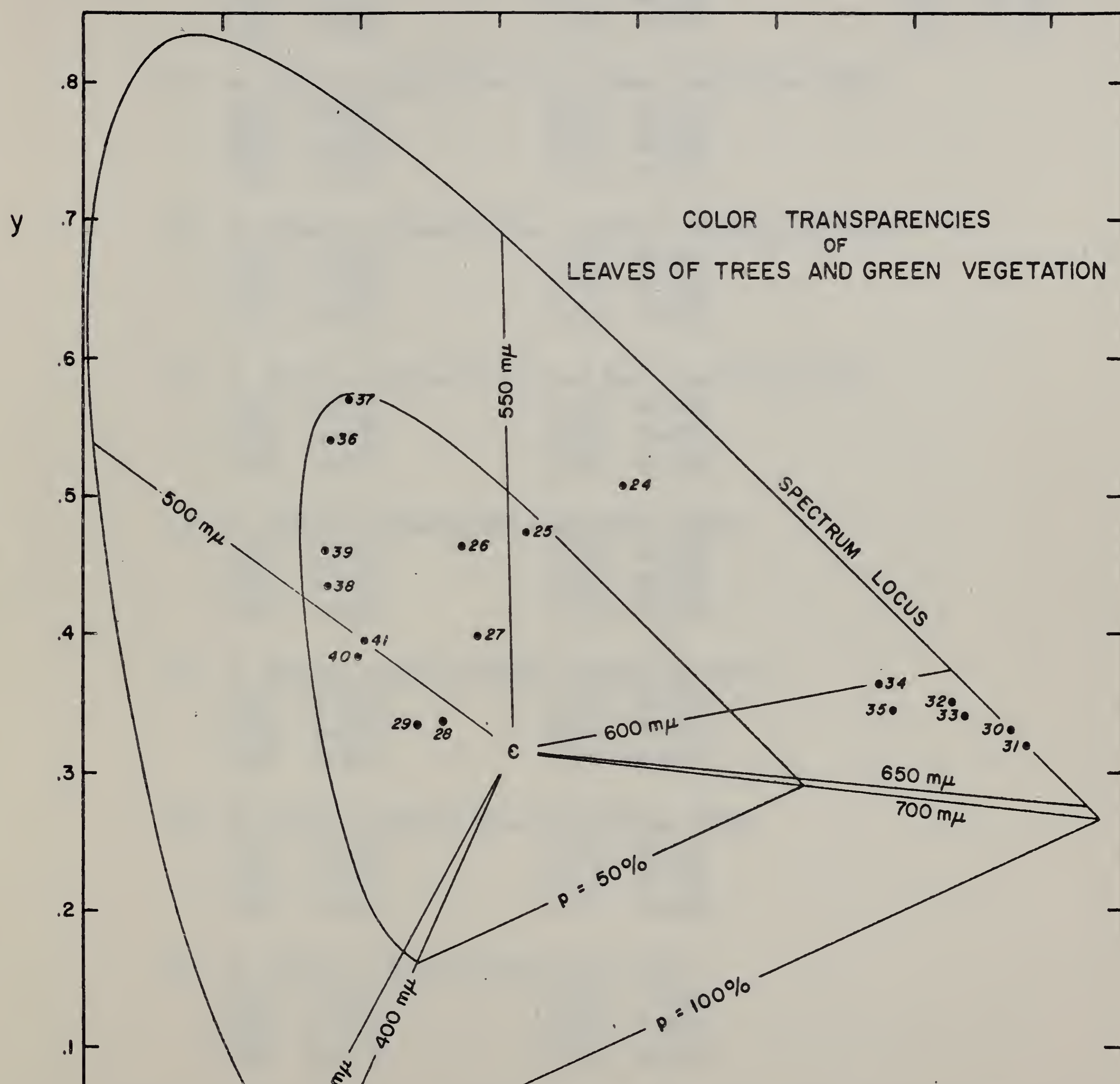

COLOR TRANSPARENCIES
OF
LEAVES OF TREES AND GREEN VEGETATION
SPECTRUM LOCUS
550 mμ
500 mμ
600 mμ
650 mμ
700 mμ
450 mμ
400 mμ
p = 50%
p = 100%
C
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
y
x
.0
.1
.2
.3
.4
.5
.6
.7
.8
NBS

FIGURE 20

Figure 21. CIE chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of color transparencies of wet sand (solid circles), dry sand (open circles), and wet gravel (solid squares).

a) On Ansco Daylight Color Film

(42) W-872	(66) W-875	(90) W-944
(43) W-873	(67) W-876	(91) W-945
(44) W-874	(68) W-877	(92) W-946

b) On Special Ansco Red and Green Sensitive Film

(45) W-890	(69) W-893
(46) W-891	(70) W-894
(47) W-892	(71) W-895

c) On Special Ansco Green and Blue Sensitive Film

(48) W-899	(72) W-902
(49) W-900	(73) W-903
(50) W-901	(74) W-904

d) On Special Ansco Blue and Red Sensitive Film

(51) W-881	(75) W-884
(52) W-882	(76) W-885
(53) W-883	(77) W-886

e) On Special Ansco Red Sensitive Film

(54) W-935	(78) W-938
(55) W-936	(79) W-939
(56) W-937	(80) W-940

f) On Special Ansco Green Sensitive Film

(57) W-926	(81) W-929
(58) W-927	(82) W-930
(59) W-928	(83) W-931

g) On Special Ansco Blue Sensitive Film

(60) W-908	(84) W-911
(61) W-909	(85) W-912
(62) W-910	(86) W-913

h) On Special Ansco Plenacolor Film

(63) W-917	(87) W-920
(64) W-918	(88) W-921
(65) W-919	(89) W-922

Shown also are the data for the wet sand, Sample No. (2), and the dry sand, Sample No. (5).

(For identification of the samples, shutter speed, and aperture, see Table I).

Figure 21. CIE chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of color transparencies of wet sand (solid circles), dry sand (open circles), and wet gravel (solid squares).

a) On Ansco Daylight Color Film

(42) W-872	(66) W-875	(90) W-944
(43) W-873	(67) W-876	(91) W-945
(44) W-874	(68) W-877	(92) W-946

b) On Special Ansco Red and Green Sensitive Film

(45) W-890	(69) W-893
(46) W-891	(70) W-894
(47) W-892	(71) W-895

c) On Special Ansco Green and Blue Sensitive Film

(48) W-899	(72) W-902
(49) W-900	(73) W-903
(50) W-901	(74) W-904

d) On Special Ansco Blue and Red Sensitive Film

(51) W-881	(75) W-884
(52) W-882	(76) W-885
(53) W-883	(77) W-886

e) On Special Ansco Red Sensitive Film

(54) W-935	(78) W-938
(55) W-936	(79) W-939
(56) W-937	(80) W-940

f) On Special Ansco Green Sensitive Film

(57) W-926	(81) W-929
(58) W-927	(82) W-930
(59) W-928	(83) W-931

g) On Special Ansco Blue Sensitive Film

(60) W-908	(84) W-911
(61) W-909	(85) W-912
(62) W-910	(86) W-913

h) On Special Ansco Plenacolor Film

(63) W-917	(87) W-920
(64) W-918	(88) W-921
(65) W-919	(89) W-922

Shown also are the data for the wet sand, Sample No. (2), and the dry sand, Sample No. (5).

(For identification of the samples, shutter speed, and aperture, see Table I).

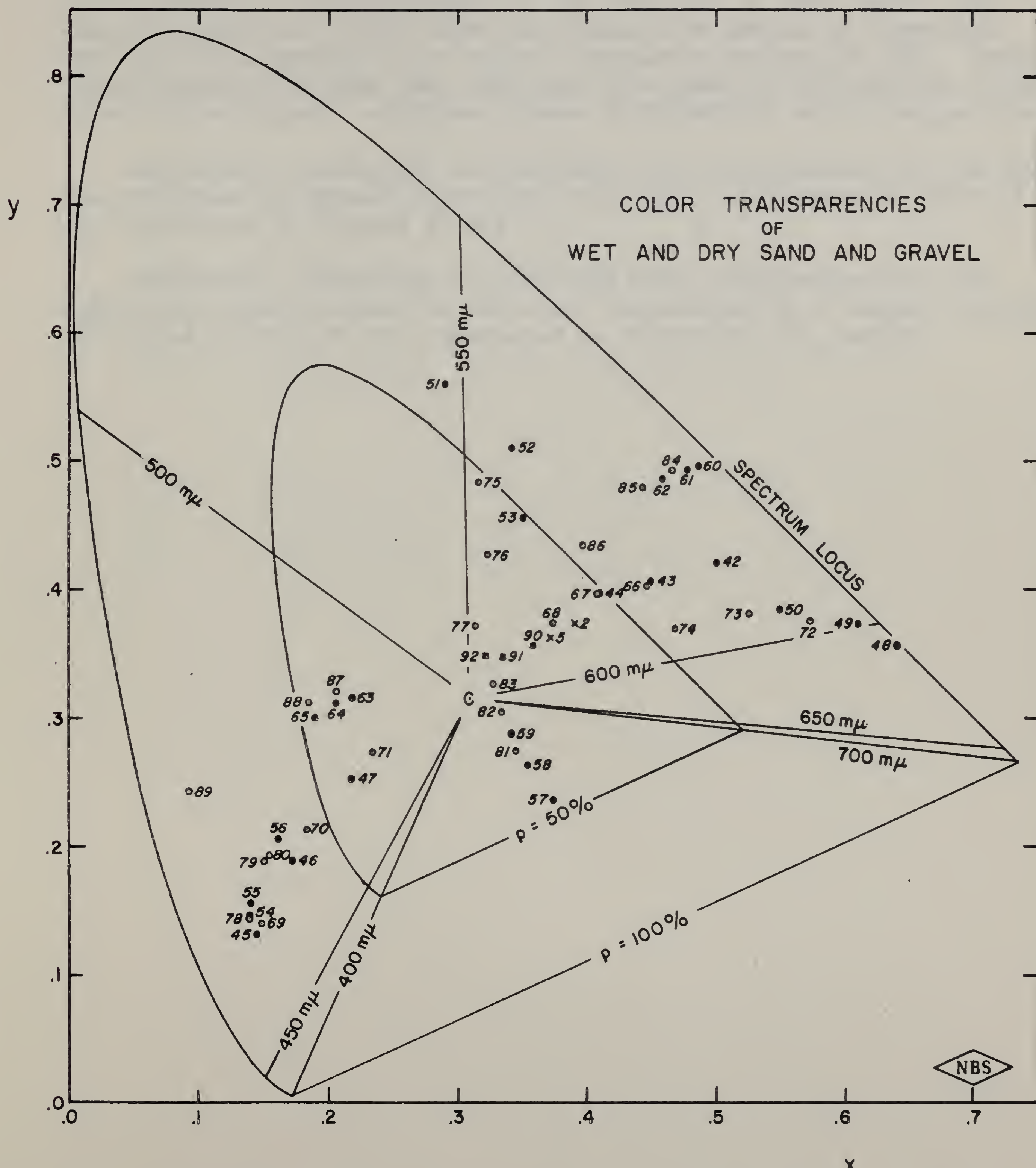

COLOR TRANSPARENCIES
OF
WET AND DRY SAND AND GRAVEL
SPECTRUM LOCUS
y
x
500 mμ
550 mμ
600 mμ
650 mμ
700 mμ
450 mμ
400 mμ
p = 50%
p = 100%
C
NBS
.0
.1
.2
.3
.4
.5
.6
.7
.8

FIGURE 21

VII. Munsell Renotations and ISCC-NBS Color Designations

From the above-mentioned determinations of the C.I.E. chromaticity coordinates and of daylight reflectances or of daylight transmittances of the ninety-six determinations of the specimens of this report, the Munsell renotations (H V/C) were determined from graphs of conversion from the C.I.E. system to the Munsell renotation system [17, 18]. These Munsell renotations were then converted into terms of the ISCC-NBS (Inter-Society Color Council - National Bureau of Standards) color designations [19].

The Munsell renotations and ISCC-NBS color designations for the eleven determinations on natural objects of this report are listed in Table IV and illustrated in Figures 22 and 23.

The Munsell renotations and ISCC-NBS color designations for the eighty-five determinations on the color transparencies of natural objects are listed in Table V and illustrated in Figures 24, 25, and 26.

Table IV

Reflecting Natural Objects

Munsell Renotations and ISCC-NBS Color Designations of the Indicated Samples.

Sample Number	Munsell Renotations	ISCC-NBS Color Designations
		Sand and Soil
(1)	0.2Y 5.2/2.3	Grayish yellowish brown
(2)	8.6YR 5.1/3.7	Moderate yellowish brown
(3)	9.2YR 4.6/1.8	Grayish yellowish brown
(4)	9.8YR 6.6/2.2	Light grayish yellowish brown
(5)	8.9YR 6.6/3.6	Light yellowish brown
(6)	9.0YR 5.8/1.3	Light grayish yellowish brown
(7)	9.6YR 4.4/1.5	Grayish yellowish brown
		Barks of Trees
(93)	8.0YR 4.0/1.7	Grayish yellowish brown
(94)	5.6YR 4.4/2.5	Grayish brown
(95)	0.9GY 5.8/1.1	Light olive gray
(96)	9.7YR 3.2/1.5	Dark grayish yellowish brown

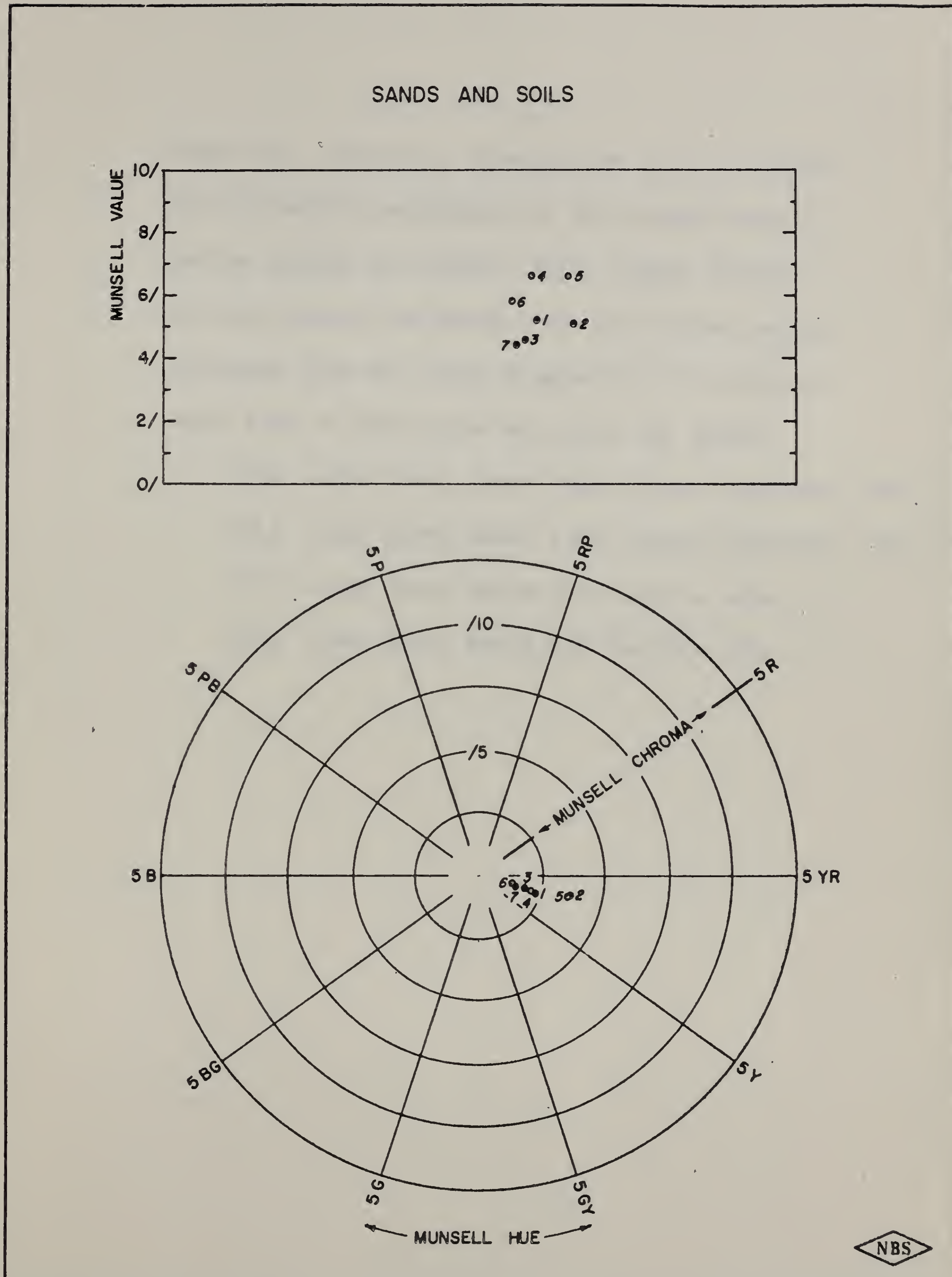

SANDS AND SOILS
MUNSELL VALUE
10/
8/
6/
4/
2/
0/
5 P
5 RP
5 PB
5 R
5 B
5 YR
5 BG
5 Y
5 G
5 GY
/10
/5
MUNSELL CHROMA
MUNSELL HUE
NBS

FIGURE 22

Figure 23. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against the Munsell Hue and Chroma points projected from the lower diagram of the inner and outer bark of scrub pine and white oak trees.

(93) Outer Bark, Scrub Pine (Pinus virginiana, Mill.)

(94) Inner Bark, Scrub Pine (Pinus virginiana, Mill.)

(95) Outer Bark, White Oak (Quercus alba, L.)

(96) Inner Bark, White Oak (Quercus alba, L.)

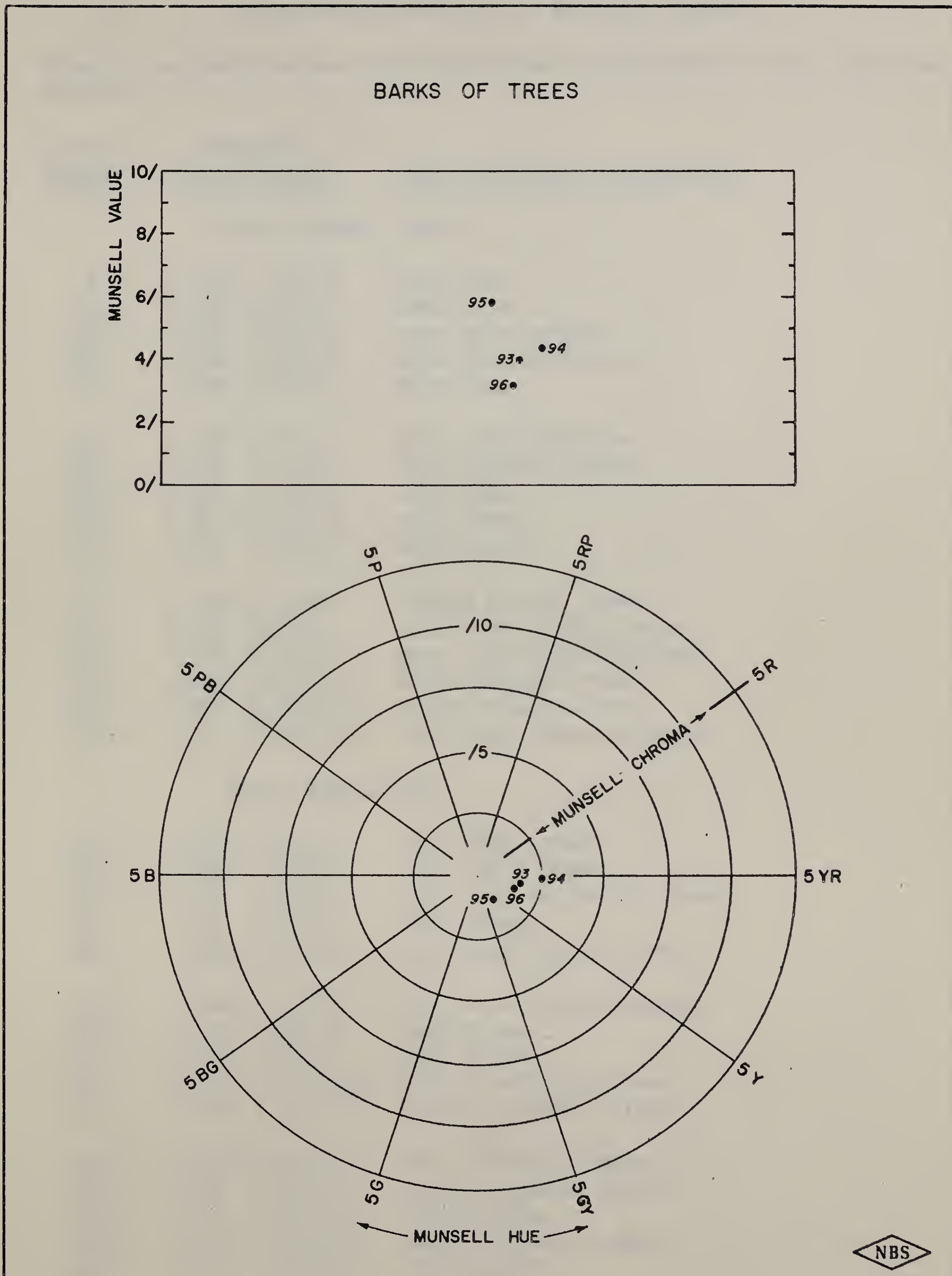

BARKS OF TREES
MUNSELL VALUE
10/
8/
6/
4/
2/
0/
95
94
93
96
5P
5RP
/10
5PB
5R
/5
MUNSELL CHROMA
5B
5YR
93
94
95
96
5BG
5Y
5G
5GY
MUNSELL HUE
NBS

FIGURE 23

Table V

Color Transparencies of Natural Objects

Munsell Renotations and ISCC-NBS Color Designations of the Indicated Samples.

Sample Number	Munsell Renotations	ISCC-NBS Color Designations
	Sky, Clouds, Water	
(8)	4.9PB 1.8/4.9	Dark blue
(9)	5.6PB 3.0/3.2	Dark blue
(10)	4.0BG 7.7/1.4	Very pale green
(11)	5.4PB 2.8/2.9	Dark grayish blue
(12)	2.1PB 1.2/2.7	Dark blue
(13)	7.7PB 0.9/2.1	Dark purplish blue
(14)	9.6BG 2.2/0.6	Dark grayish green
(15)	6.0Y 3.2/0.2	Dark gray
(16)	5.6BG 6.3/1.6	Pale green
(17)	9.5G 7.4/1.7	Pale green
(18)	6.4BG 4.2/10.3	Strong bluish green
(19)	8.7BG 6.9/7.1	Brilliant bluish green
(20)	7.8BG 8.0/3.6	Very light bluish green
(21)	2.4BG 3.4/11.3	Vivid bluish green
(22)	5.3B 4.2/11.1	Vivid greenish blue
(23)	4.3B 5.6/10.6	Brilliant greenish blue
	Green Vegetation	
(24)	3.2GY 1.6/4.0	Very dark green
(25)	7.6GY 1.5/4.0	Dark olive green
(26)	0.3G 1.2/3.9	Very dark yellowish green
(27)	5.7G 2.1/2.5	Dark green
(28)	1.3BG 1.5/2.5	Very dark bluish green
(29)	2.2BG 1.0/2.6	Very dark bluish green
(30)	2.7YR 1.3/8.6	Deep brown
(31)	3.4YR 0.5/4.3	Dark brown
(32)	0.2YR 3.3/12.6	Strong reddish brown
(33)	0.3YR 3.0/12.2	Strong reddish brown
(34)	0.4YR 4.1/11.8	Deep reddish orange
(35)	9.5R 3.5/11.2	Strong reddish brown
(36)	3.4G 3.2/12.3	Vivid green
(37)	2.2G 3.1/12.4	Deep yellowish green
(38)	7.6G 3.7/11.2	Vivid green

Table V (Continued)

Sample Number	Munsell Renotations	ISCC-NBS Color Designations
	Green Vegetation (Continued)	
(39)	6.2G 3.6/11.6	Vivid green
(40)	0.3BG 4.5/9.8	Strong bluish green
(41)	9.3G 4.4/9.8	Strong bluish green
	Wet Sand	
(42)	9.1YR 1.5/3.7	Dark yellowish brown
(43)	9.3YR 3.0/4.5	Deep yellowish brown
(44)	1.2Y 4.2/3.9	Moderate olive brown
(45)	3.9PB 2.9/12.1	Vivid blue
(46)	1.5PB 4.2/10.5	Strong blue
(47)	8.5B 5.7/7.5	Brilliant greenish blue
(48)	0.6YR 3.4/13.5	Strong reddish brown
(49)	1.5YR 4.0/14.0	Vivid reddish orange
(50)	1.8R 4.9/11.8	Strong reddish orange
(51)	0.2G 5.0/11.7	Vivid yellowish green
(52)	7.8GY 6.3/10.0	Strong yellow green
(53)	6.7GY 7.3/8.0	Strong yellow green
(54)	2.0PB 4.0/14.9	Vivid blue
(55)	1.3PB 4.3/14.5	Vivid blue
(56)	7.8B 5.4/12.3	Vivid greenish blue
(57)	3.2RP 4.8/11.7	Strong purplish red
(58)	2.9RP 6.0/9.6	Deep purplish pink
(59)	3.4RP 7.1/6.4	Moderate purplish pink
(60)	4.1Y 8.1/16.4	Vivid yellow
(61)	4.6Y 8.2/15.1	Vivid yellow
(62)	5.6Y 8.4/13.1	Vivid yellow
(63)	5.2BG 2.7/5.2	Dark bluish green
(64)	5.2BG 2.0/4.7	Very dark bluish green
(65)	5.8BG 1.1/3.8	Very dark bluish green
	Dry Sand	
(66)	9.5YR 2.1/3.6	Dark yellowish brown
(67)	0.5Y 3.3/3.6	Dark yellowish brown
(68)	2.1Y 4.5/2.7	Light olive brown
(69)	3.8PB 3.2/12.3	Strong blue
(70)	9.9B 4.8/9.9	Strong blue

Table V (Continued)

Sample Number	Munsell Renotations	ISCC-NBS Color Designations
	Dry Sand (Continued)	
(71)	6.0B 6.4/6.1	Light greenish blue
(72)	1.1YR 4.5/12.6	Deep reddish orange
(73)	1.6YR 5.2/10.8	Moderate reddish orange
(74)	1.3YR 5.9/7.1	Moderate reddish orange
(75)	9.6GY 6.5/9.8	Brilliant yellowish green
(76)	8.8GY 7.4/7.2	Brilliant yellowish green
(77)	10.0GY 8.2/3.8	Light yellowish green
(78)	2.0PB 4.1/15.0	Vivid blue
(79)	9.0B 5.1/13.5	Vivid blue
(80)	8.4B 5.2/13.2	Vivid greenish blue
(81)	2.8RP 6.7/7.9	Moderate purplish pink
(82)	5.2RP 7.9/4.4	Pale purplish pink
(83)	3.2YR 8.8/1.5	Faint pink
(84)	5.3Y 8.3/14.2	Vivid yellow
(85)	6.6Y 8.5/11.8	Vivid yellow
(86)	7.6Y 8.8/7.5	Light greenish yellow
(87)	4.1BG 1.2/3.6	Very dark bluish green
(88)	4.3BG 0.5/2.4	Very dark bluish green
(89)	6.0BG 0.1/1.4	Blackish green
	Wet Gravel	
(90)	1.1Y 3.8/1.7	Moderate olive brown
(91)	5.6Y 5.0/1.3	Light olive gray
(92)	5.9GY 6.4/1.6	Grayish yellow green

Figure 24. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against the Munsell Hue and Chroma points projected from the lower diagram of color transparencies of sky, clouds, water, and seaweed:

a) On Ansco Daylight Color Film

(8)	W-68	(13)	W-73
(9)	W-69	(14)	W-73
(10)	W-70	(15)	W-300
(11)	W-71	(16)	W-301
(12)	W-72	(17)	W-302

b) On Special Ansco Blue and Red Sensitive Film

(18)	W-177	(21)	W-180
(19)	W-178	(22)	W-181
(20)	W-179	(23)	W-182

(For identification of the samples, shutter speed, and aperture, see Table I. Note, when the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

COLOR TRANSPARENCIES
OF
SKY, CLOUDS, WATER, AND SEAWEED

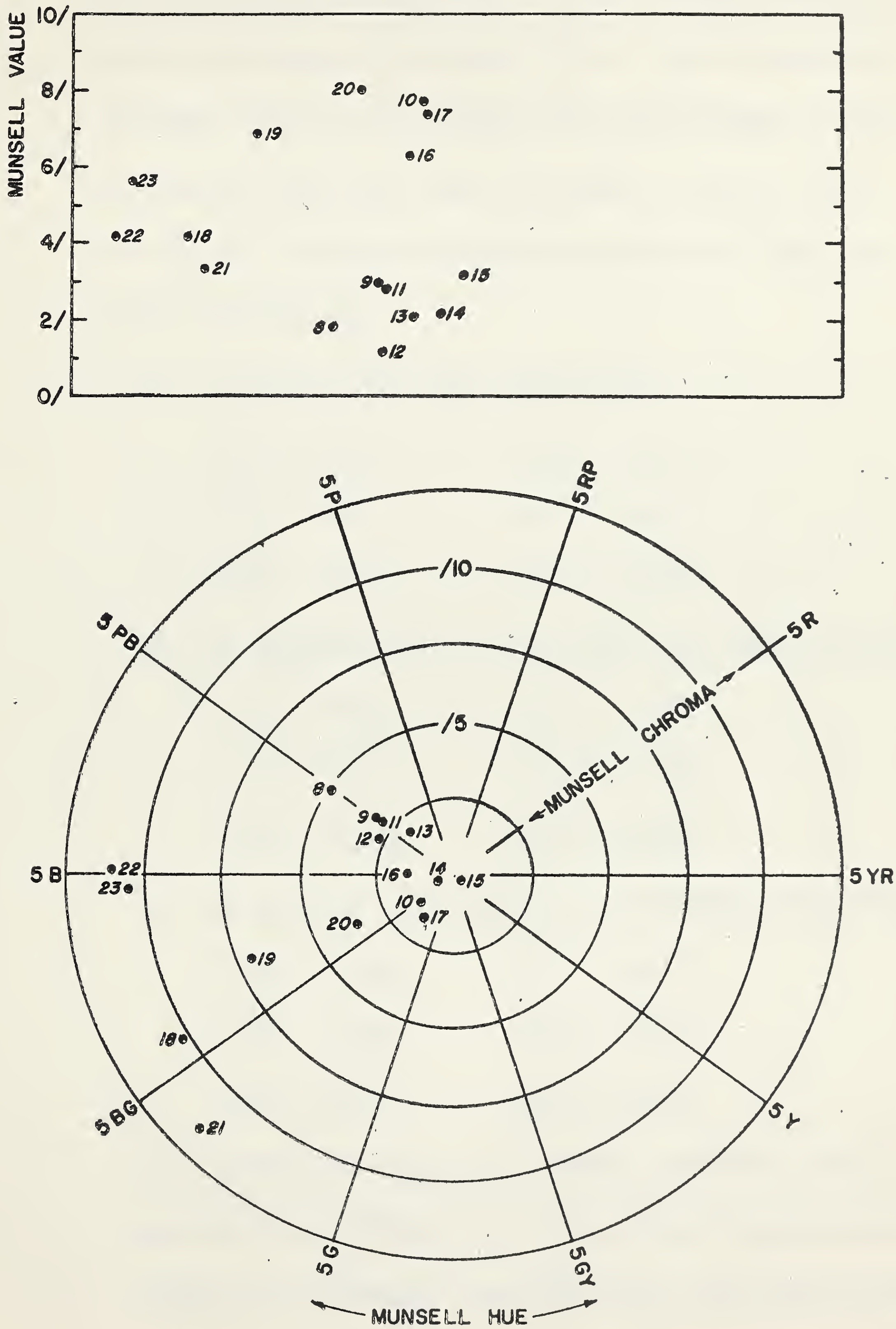


FIGURE 24

Figure 25. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against the Munsell Hue and Chroma points projected from the lower diagram of color transparencies of green and yellow leaves of trees and green vegetation:

a) On Ansco Daylight Color Film

(24) W-80	(27) W-122
(25) W-81	(28) W-123
(26) W-121	(29) W-131

b) On Special Ansco Green and Blue Sensitive Film

(30) W-143	(33) W-144
(31) W-143	(34) W-145
(32) W-144	(35) W-145

c) On Special Ansco Blue and Red Sensitive Film

(36) W-174	(39) W-175
(37) W-174	(40) W-176
(38) W-175	(41) W-176

(For identification of samples, shutter speed, and aperture, see Table I. Note, when the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

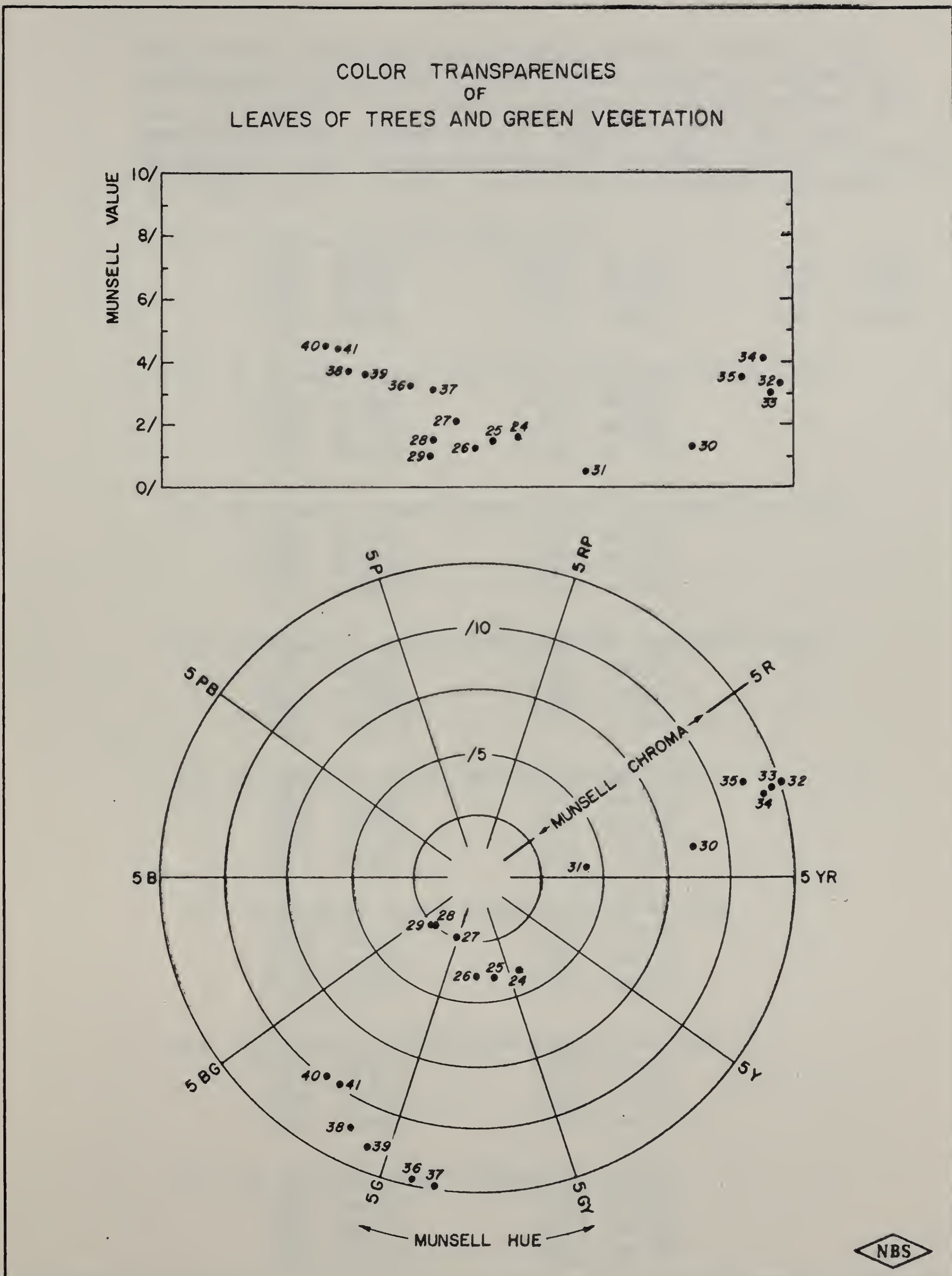

COLOR TRANSPARENCIES
OF
LEAVES OF TREES AND GREEN VEGETATION
MUNSELL VALUE
10/
8/
6/
4/
2/
0/
40
41
38
39
36
37
27
28
29
26
25
24
31
30
34
35
32
33
5P
5RP
/10
5PB
5R
/5
MUNSELL CHROMA
5B
5YR
5BG
5Y
5G
5GY
MUNSELL HUE
NBS

FIGURE 25

Figure 26. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against the Munsell Hue and Chroma points projected from the lower diagram of color transparencies of wet sand (solid circles), dry sand (open circles), and wet gravel (solid squares):

a) On Ansco Daylight Color Film

(42) W-872	(66) W-875	(90) W-944
(43) W-873	(67) W-876	(91) W-945
(44) W-874	(68) W-877	(92) W-946

b) On Special Ansco Red and Green Sensitive Film

(45) W-890	(69) W-893
(46) W-891	(70) W-894
(47) W-892	(71) W-895

c) On Special Ansco Green and Blue Sensitive Film

(48) W-899	(72) W-902
(49) W-900	(73) W-903
(50) W-901	(74) W-904

d) On Special Ansco Blue and Red Sensitive Film

(51) W-881	(75) W-884
(52) W-882	(76) W-885
(53) W-883	(77) W-886

e) On Special Ansco Red Sensitive Film

(54) W-935	(78) W-938
(55) W-936	(79) W-939
(56) W-937	(80) W-940

f) On Special Ansco Green Sensitive Film

(57) W-926	(81) W-929
(58) W-927	(82) W-930
(59) W-928	(83) W-931

g) On Special Ansco Blue Sensitive Film

(60) W-908	(84) W-911
(61) W-909	(85) W-912
(62) W-910	(86) W-913

h) On Special Ansco Plenacolor Film

(63) W-917	(87) W-920
(64) W-918	(88) W-921
(65) W-919	(89) W-922

(For identification of the samples, shutter speed, and aperture, see Table I).

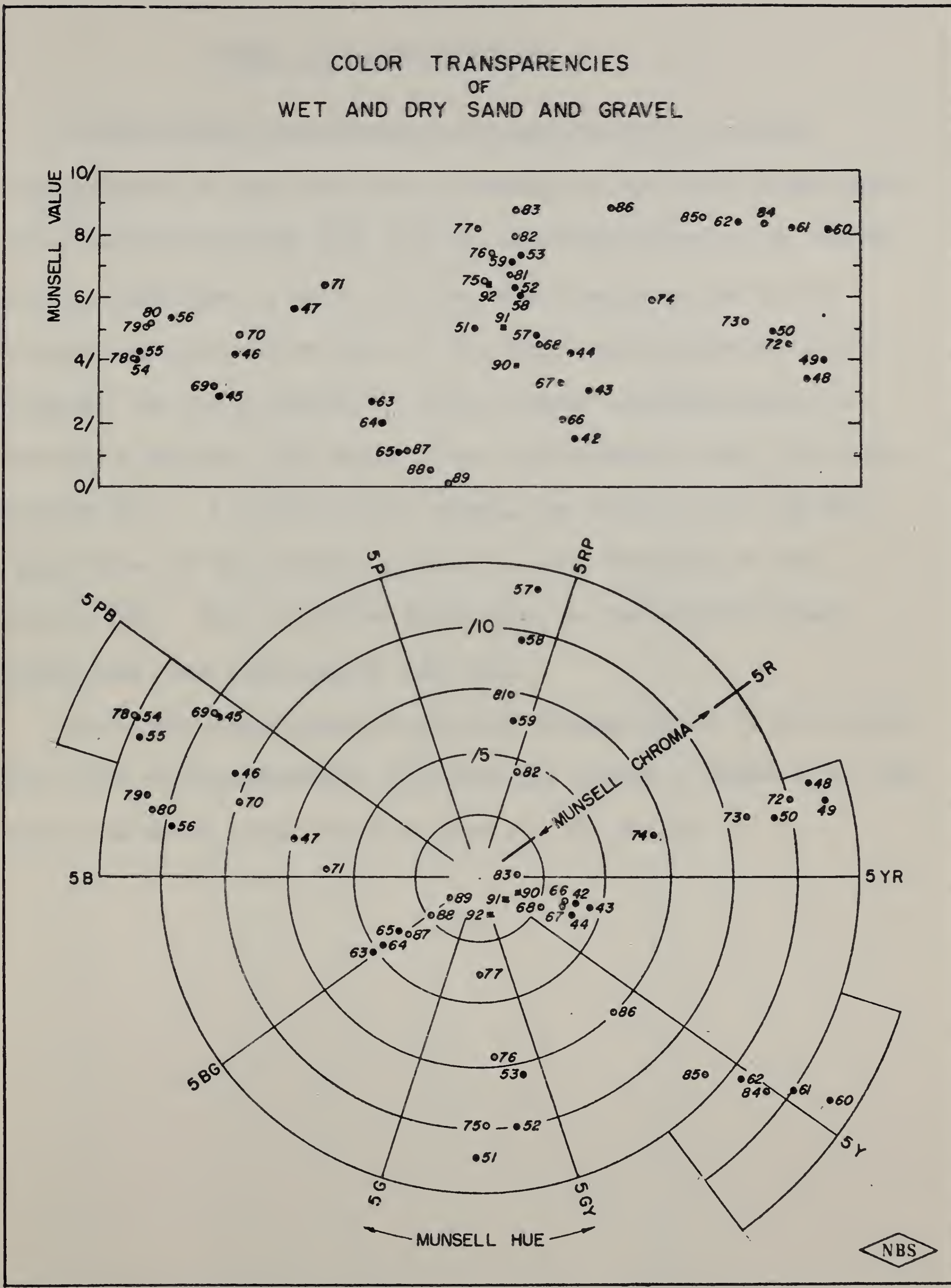

COLOR TRANSPARENCIES
OF
WET AND DRY SAND AND GRAVEL
MUNSELL VALUE
MUNSELL CHROMA
MUNSELL HUE
5 B
5 PB
5 P
5 RP
5 R
5 YR
5 Y
5 GY
5 G
5 BG
NBS

FIGURE 26

VIII. Lovibond Notations

In order that a comparison may be made between the color transparencies of this test and a standardized system of transparent media, conversions were made from the above-mentioned C.I.E. chromaticity coordinates, x and z, of the color transparencies to the Lovibond designations by means of the large scale graphs printed on aluminum, for C.I.E. source C, of the "ideal" Lovibond system as derived by Scofield [20] and sold by the Tintometer Ltd., Salisbury, England [21] . A similar C.I.E. graph, for source C, for the NBS standard set of the Lovibond glasses is also available in this country [22]. This and other information on the Lovibond Color System have been published by Judd [23].

The Lovibond analyses and daylight transmittances of the eighty-five color transparencies of this test are listed in Table VI of this report and are illustrated in Figures 27, 28, and 29.

Table VI

Color Transparencies of Natural Objects

Lovibond Analysis and Daylight Transmittance, for Source C, of the Indicated Samples.

Sample Number	Lovibond Analysis R	Y	B	Daylight Transmittance Y(%)
	Sky, Clouds, Water			
(8)	0.0	0.2	7.2	2.6
(9)	0.3	0.0	3.5	6.4
(10)	0.0	0.9	1.4	54.6
(11)	0.3	0.0	3.2	5.9
(12)	0.0	0.8	6.3	1.5
(13)	0.0	1.7	7.4	1.1
(14)	0.0	0.5	1.1	3.6
(15)	0.1	0.3	0.0	7.7
(16)	0.0	1.2	2.0	33.6
(17)	0.0	1.5	2.0	49.4
(18)	0.0	20.	28.	13.1
(19)	0.0	5.0	8.5	41.4
(20)	0.0	2.2	3.7	59.9
(21)	Outside Gamut			8.2
(22)	0.0	11.2	24.4	13.6
(23)	0.0	7.9	16.9	25.5
	Green Vegetation			
(24)	0.0	18.0	2.6	2.2
(25)	0.0	13.6	6.3	2.0
(26)	0.0	17.2	10.8	1.5
(27)	0.0	7.9	6.5	3.4
(28)	0.0	4.5	6.2	2.0
(29)	0.0	5.4	8.0	1.3
(30)	46.	100.	0.0	1.7
(31)	58.	100.	0.0	0.5
(32)	27.	14.	0.0	8.1
(33)	31.5	10.	0.0	6.5
(34)	16.7	12.	0.0	12.5
(35)	21.5	6.4	0.0	8.8
(36)	Outside Gamut			7.3
(37)	Outside Gamut			7.1
(38)	Outside Gamut			10.3

Table VI (Continued)

Sample Number	Lovibond Analysis R	Y	B	Daylight Transmittance Y(%)
		Green Vegetation (Continued)		
(39)	Outside Gamut			9.3
(40)	0.0	20.0	19.8	15.3
(41)	0.0	20.0	19.4	15.1
		Wet Sand		
(42)	7.0	13.9	0.0	2.0
(43)	5.4	7.0	0.0	6.4
(44)	3.1	5.0	0.0	13.0
(45)	0.0	6.3	24.	6.0
(46)	0.0	3.7	14.6	13.0
(47)	0.0	6.7	10.9	26.5
(48)	29.	30.	0.0	8.5
(49)	19.2	25.	0.0	12.1
(50)	12.7	12.	0.0	19.0
(51)	0.0	33.	14.5	19.3
(52)	0.0	18.	5.7	34.2
(53)	0.0	9.1	2.8	48.1
(54)	0.0	10.2	28.5	12.2
(55)	0.0	9.9	27.	14.1
(56)	0.0	13.5	22.	23.1
(57)	13.5	0.0	2.3	17.7
(58)	7.2	0.0	0.8	30.3
(59)	4.1	0.0	0.2	44.2
(60)	3.0	60.	0.0	60.7
(61)	2.4	45.	0.0	63.0
(62)	2.2	20.0	0.0	65.7
(63)	0.0	7.6	11.8	5.2
(64)	0.0	8.8	13.8	3.0
(65)	0.0	9.4	15.9	1.4
		Dry Sand		
(66)	4.8	7.0	0.0	3.5
(67)	3.3	5.6	0.0	7.8
(68)	2.2	2.6	0.0	15.9
(69)	0.0	5.7	22.0	7.7
(70)	0.0	4.0	13.2	18.3

Table VI (Continued)

Sample Number	Lovibond Analysis R	Y	B	Daylight Transmittance Y(%)
		Dry Sand (Continued)		
(71)	0.0	2.4	6.6	35.3
(72)	15.8	13.	0.0	15.4
(73)	11.0	9.5	0.0	21.4
(74)	7.9	5.5	0.0	28.5
(75)	0.0	14.3	6.7	36.7
(76)	0.0	7.9	3.9	49.7
(77)	0.0	3.2	2.4	61.9
(78)	0.0	10.5	30.	12.6
(79)	0.0	9.1	22.0	20.5
(80)	0.0	8.2	20.9	21.6
(81)	5.1	0.0	0.5	38.7
(82)	2.5	0.2	0.0	57.8
(83)	1.0	0.5	0.0	73.8
(84)	1.7	34.	0.0	64.9
(85)	1.2	18.0	0.0	69.0
(86)	1.4	6.2	0.0	73.7
(87)	0.0	9.7	14.4	1.5
(88)	0.0	11.2	17.3	0.6
(89)	Outside Gamut			0.1
		Wet Gravel		
(90)	2.0	1.8	0.0	10.5
(91)	0.6	1.2	0.0	19.8
(92)	0.0	1.4	0.5	35.6

Figure 27. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram of color transparencies of sky, clouds, water, and seaweed:

a) On Ansco Daylight Color Film

(8)	W-68	(13)	W-73
(9)	W-69	(14)	W-73
(10)	W-70	(15)	W-300
(11)	W-71	(16)	W-301
(12)	W-72	(17)	W-302

b) On Special Ansco Blue and Red Sensitive Film

(18)	W-177	(22)	W-181
(19)	W-178	(23)	W-182
(20)	W-179		

(For identification of samples, shutter speed, and aperture, see Table I. Note, when the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

Sample No. (21) is not shown on the diagram as this saturated green color is outside the gamut of the Lovibond Color System.

COLOR TRANSPARENCIES
OF
SKY, CLOUDS, WATER, AND SEAWEED

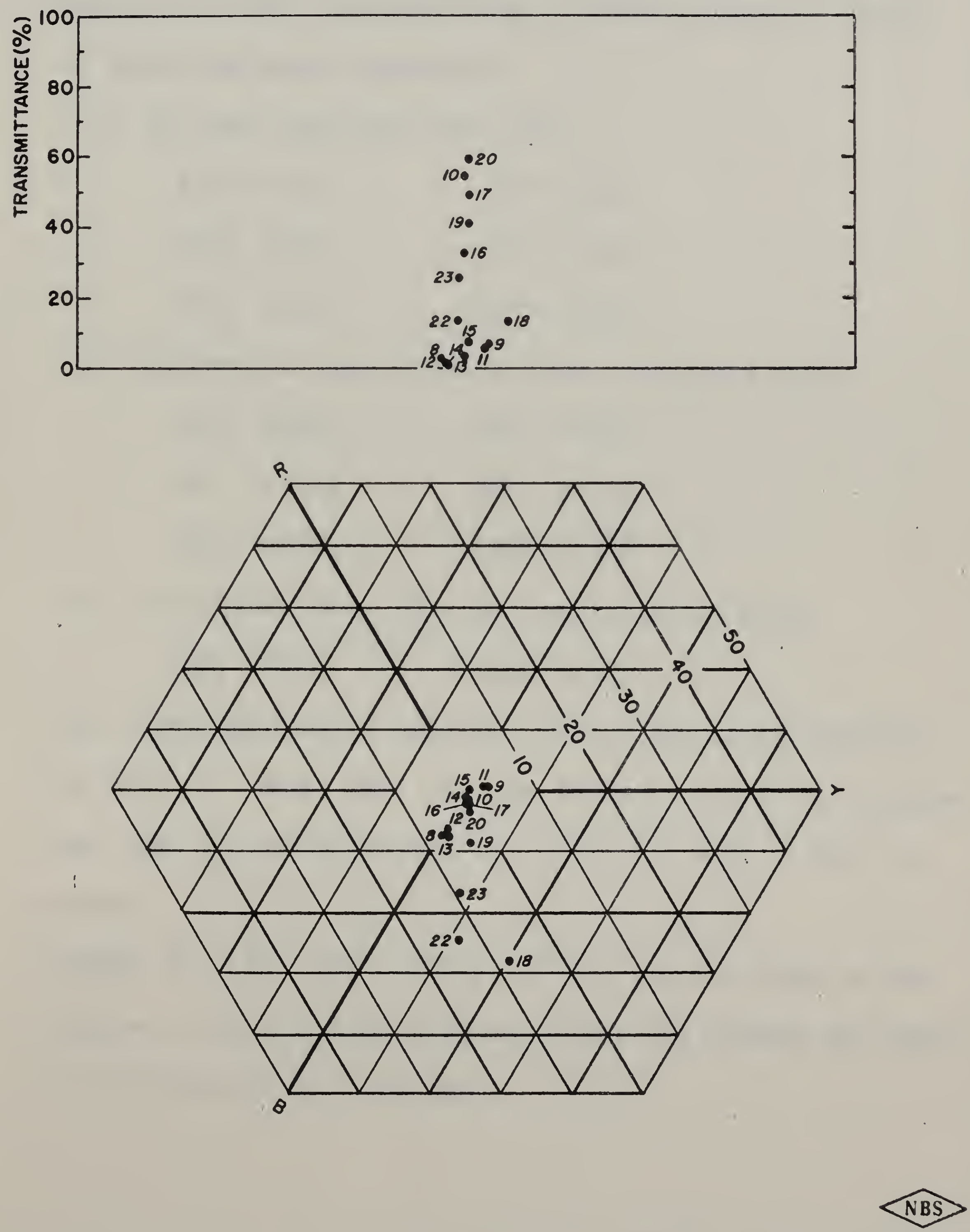


FIGURE 27

Figure 28. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram of color transparencies of green and yellow leaves of trees and green vegetation:

a) On Ansco Daylight Color Film

(24) W-80	(27) W-122
(25) W-81	(28) W-123
(26) W-121	(29) W-131

b) On Special Ansco Green and Blue Sensitive Film

(30) W-143	(33) W-144
(31) W-143	(34) W-145
(32) W-144	(35) W-145

c) On Special Ansco Blue and Red Sensitive Film

(40) W-176	(41) W-176

(For identification of samples, shutter speed, and aperture, see Table I. Note, when the same exposure number is repeated, more than one spectrophotometric curve was made of that exposure).

Samples No. (36), (37), (38), and (39) are not shown on the diagram as these saturated green colors are outside the gamut of the Lovibond Color System.

COLOR TRANSPARENCIES
OF
LEAVES OF TREES AND GREEN VEGETATION

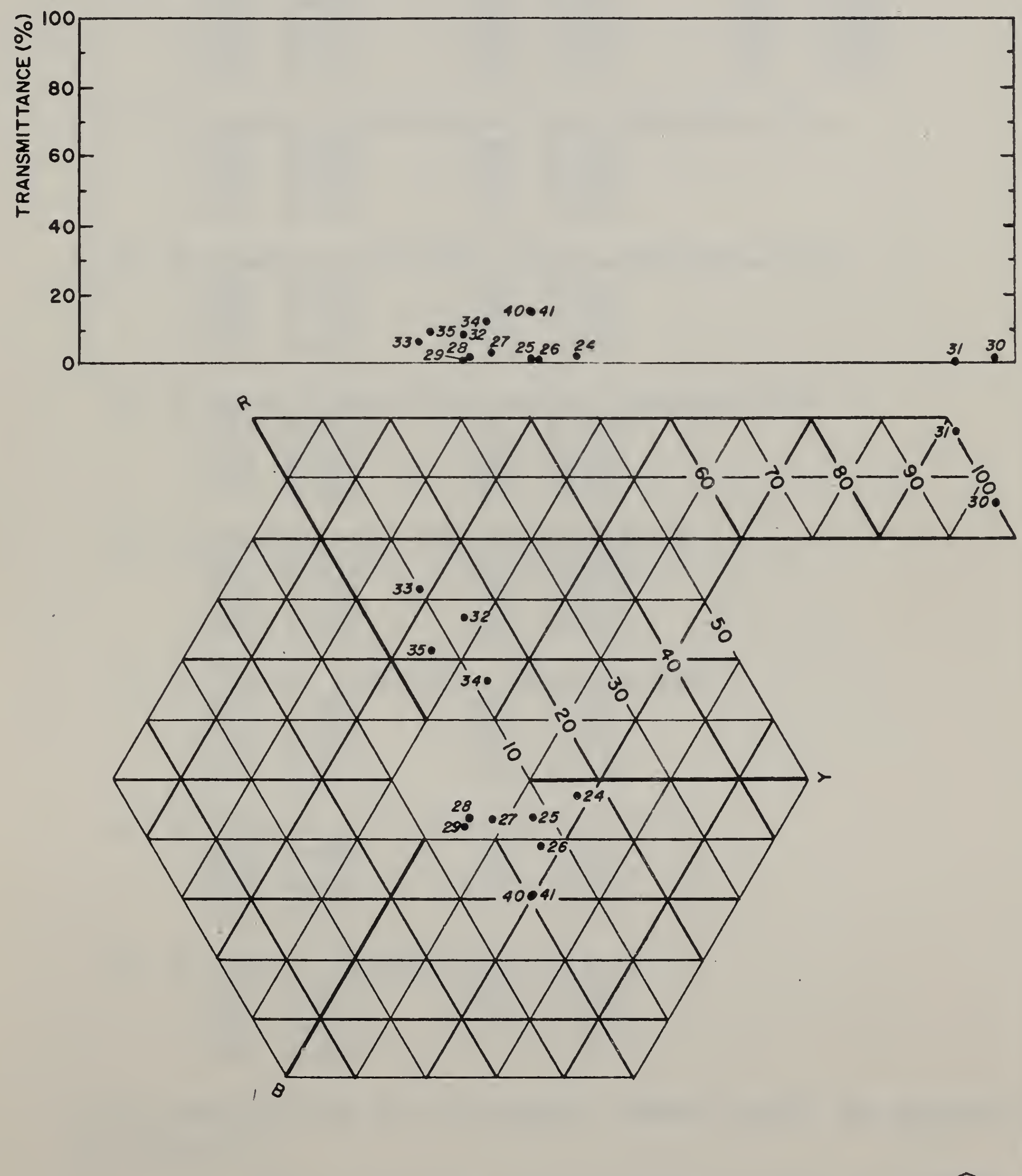


FIGURE 28

Figure 29. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram of color transparencies of wet sand (solid circles), dry sand (open circles), and wet gravel (solid squares):

a) On Ansco Daylight Color Film

(42) W-872	(66) W-875	(90) W-944
(43) W-873	(67) W-876	(91) W-945
(44) W-874	(68) W-877	(92) W-946

b) On Special Ansco Red and Green Sensitive Film

(45) W-890	(69) W-893
(46) W-891	(70) W-894
(47) W-892	(71) W-895

c) On Special Ansco Green and Blue Sensitive Film

(48) W-899	(72) W-902
(49) W-900	(73) W-903
(50) W-901	(74) W-904

d) On Special Ansco Blue and Red Sensitive Film

(51) W-881	(75) W-884
(52) W-882	(76) W-885
(53) W-883	(77) W-886

e) On Special Ansco Red Sensitive Film

(54) W-935	(78) W-938
(55) W-936	(79) W-939
(56) W-937	(80) W-940

f) On Special Ansco Green Sensitive Film

(57) W-926	(81) W-929
(58) W-927	(82) W-930
(59) W-928	(83) W-931

g) On Special Ansco Blue Sensitive Film

(60) W-908	(84) W-911
(61) W-909	(85) W-912
(62) W-910	(86) W-913

h) On Special Ansco Plenacolor Film

(63) W-917	(87) W-920
(64) W-918	(88) W-921
(65) W-919	

(For identification of the samples, shutter speed, and aperture, see Table I).

Sample No. (89) is not shown on the diagram as this saturated green color is outside the gamut of the Lovibond Color System.

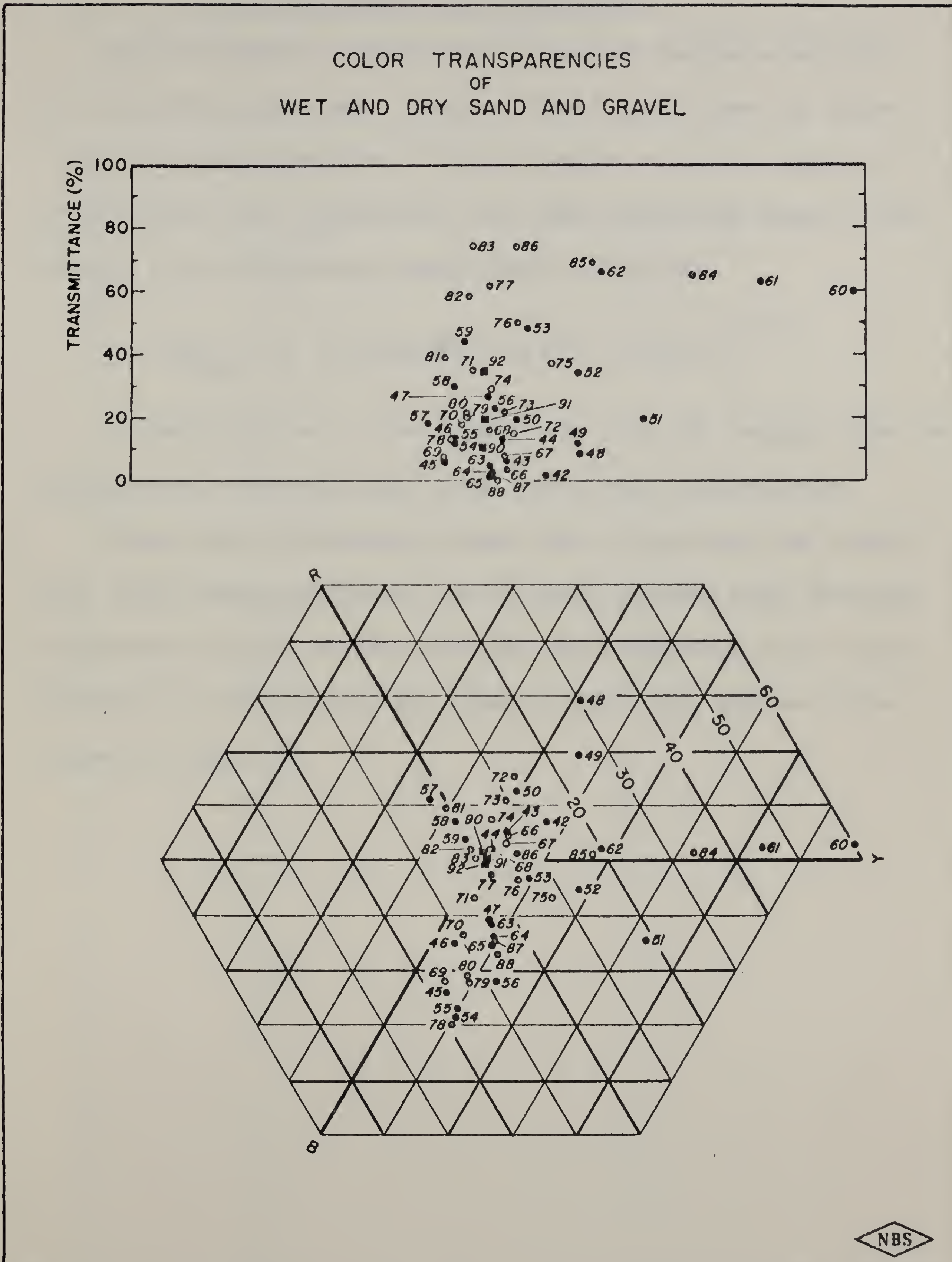

COLOR TRANSPARENCIES
OF
WET AND DRY SAND AND GRAVEL
TRANSMITTANCE (%)
100
80
60
40
20
0
R
Y
B
60
50
40
30
20
NBS

FIGURE 29

IX. Color Difference Computations

From the Munsell renotations of the two samples of wet and dry yellowish quartz sand (samples 2 and 5), and from the forty-eight color transparencies of these samples on various types of color films, color differences have been computed by means of the Godlove color difference formula [24], as follows:

$$\Delta E_{NBS} = 5 \left[2C_1C_2\,\phi(H) + (\Delta C)^2 + (4\Delta V)^2 \right]^{1/2}$$

where $\phi(H) = 1 - \cos 3.6\Delta H$; and ΔH, ΔV, and ΔC refer to differences in Munsell hue, value, and chroma, respectively.

These color differences between the wet sand and the twenty-four color transparencies of the wet sand together with the color differences between the dry sand and the twenty-four color transparencies of the dry sand are shown in Table VII, and are illustrated in Figure 30.

Table VII

Color differences between wet and dry sand and their respective color transparencies computed using the Godlove Color-Difference Formula.

Color Differences Between Samples Number Reference	Comparison	Color Difference Δ E
(2)	(42)	72.0
(2)	(43)	42.2
(2)	(44)	18.3
(2)	(45)	89.8
(2)	(46)	73.0
(2)	(47)	57.2
(2)	(48)	62.2
(2)	(49)	58.2
(2)	(50)	43.0
(2)	(51)	57.6
(2)	(52)	52.6
(2)	(53)	57.0
(2)	(54)	95.2
(2)	(55)	92.2
(2)	(56)	80.2
(2)	(57)	62.1
(2)	(58)	55.2
(2)	(59)	54.6
(2)	(60)	88.4
(2)	(61)	85.4
(2)	(62)	82.4
(2)	(63)	63.0
(2)	(64)	72.9
(2)	(65)	87.1
(5)	(66)	90.0
(5)	(67)	66.0
(5)	(68)	42.4
(5)	(69)	104.1
(5)	(70)	76.5
(5)	(71)	48.5
(5)	(72)	63.7
(5)	(73)	47.8
(5)	(74)	25.4
(5)	(75)	47.5
(5)	(76)	38.5

Table VII (Continued)

Color Differences Between Samples Number Reference	Comparison	Color Difference ΔE
(5)	(77)	39.3
(5)	(78)	105.4
(5)	(79)	90.6
(5)	(80)	88.6
(5)	(81)	44.6
(5)	(82)	37.7
(5)	(83)	45.4
(5)	(84)	64.6
(5)	(85)	58.0
(5)	(86)	50.1
(5)	(87)	112.7
(5)	(88)	125.0
(5)	(89)	132.1

Figure 30. Color differences computed by means of the Godlove color-difference formula, converted into NBS units of color difference, and plotted against the indicated exposure for wet and dry sand on the indicated types of Ansco color films. Each color difference indicated is relative to the data on the wet sand, Sample No. (2) or the dry sand, Sample No. (5).

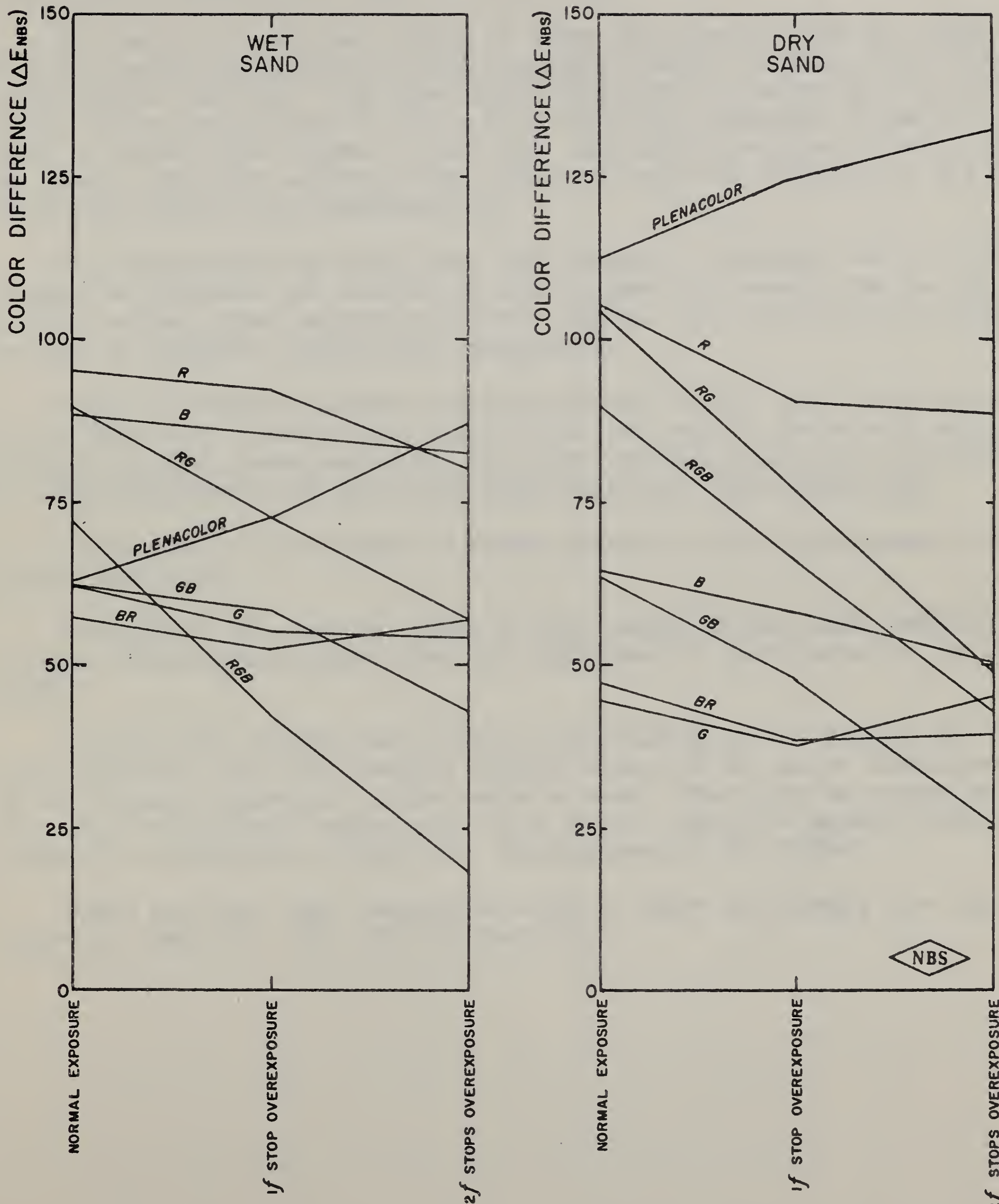

150
125
100
75
50
25
0
COLOR DIFFERENCE (ΔE NBS)
WET SAND
R
B
RG
PLENACOLOR
GB
G
BR
RGB
NORMAL EXPOSURE
1f STOP OVEREXPOSURE
2f STOPS OVEREXPOSURE
DRY SAND
PLENACOLOR
R
RG
RGB
B
GB
BR
G
NBS

FIGURE 30

X. Summary

Although an answer cannot be given to all of the questions asked by Dr. O'Neill in the work requests incident to these reports and included for this report in Appendix A (page 88), some answers as follows can be given.

Wet sands and soils are darker in color than those in the dry state, but the hue and saturation of those specimens studied for this report remain approximately the same. The same effect apparently pertains, in nearly all cases, to the photographs of the wet and dry sand regardless of the emulsion layer or layers (See Figures 21 and 26). The effect persists primarily for the nearly correctly exposed films; while an increased variation in hue and saturation results from overexposure.

The results of this study show that changes in exposure tend to cause changes in lightness and saturation with constant hue except for the red and the red and green sensitive emulsion layers, which exhibit hue shifts as well as lightness shifts when overexposed.

Color differences between the sand and the various color transparencies of the sand vary linearly with overexposure and tend to decrease in color differences with overexposure for the color reversal films and to increase in color differences for the color negative films. (See Figure 30).

Overexposures tend always to become weaker in color than normal or near normal exposures.

Photographs of a natural scene of tree leaves in the shade tend to have a higher dominant wavelength than the same scene of tree leaves in the sunlight.

In all cases studied the spectral reflectances of the objects are far from identical, with the spectral transmittances of the color transparencies of the objects regardless of the emulsion used. Thus from this study we find that the spectral reflectance of an object cannot be deduced from the spectral transmittance of the color transparency of the object.

These and many other factors involved in color photography are discussed by Evans [25, 26] and Friedman [27] .

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Appendix A. Work Requests.

Copies of the five work requests received from Dr. O'Neill authorizing studies on the natural objects and the color transparencies of natural objects herein reported are included in this appendix. It will be noted that two of the requests also authorized measurements of photographs of man-made objects. Because of the large size of this report, the man-made objects will be considered in another report of this same series (NBS Report No. 4953, in preparation).

The following are copies of the original work requests received from Dr. O'Neill for measurements and computations on some natural objects and of some of their color transparencies.

* * * *

Serial Number 2.1 WADC-23/53 June 13, 1953

"Information on the effect on the color of soil, subsoils and rocks of wetting. The color of soils, subsoil and rocks is generally much darker while wet than when dry. Changes in hue, chromaticity, etc., also occur. An example is the marble of the Lincoln Memorial which turns distinctly green to the eye when wet. Is this caused by what? What spectrophotometric data is available for this phenomenon?"

"Colors of subsoils, wet and dry, are important in the detection of fox-holes, excavations, etc., on color film; e.g. Eocene and other soils in our area resulting from weathering of glauconite (ferrous potassium silicate), turn from dull greenish to a rich raw umber. Some of Patuxent gravels turn to rich burnt umber; others are various shades of ochre."

* * * *

Serial Number 2.1 WADC-28/53 (A) July 17, 1953

"Please make spectrophotometric curves for several hundred 2-1/4 x 2-1/4 inch color transparencies, showing color fidelity, of 8 types of color (Ansco color reversal or color negative) films, as well as the spectrophotometric curves of such important military backgrounds as: sky, haze, water, vegetation soil, airplanes, army uniforms, effect of water on the chromaticity of soil, etc."

"To enable us to compare the efficiency of the various types of color photography, and of the individual layers, alone or collectively, with or without filters in the field of military reconnaissance and intelligence. Also to make use of these in conjunction with filters for increasing contrast with background when viewing such color transparencies on a light-table."

* * * *

Serial Number 2.1 WADC-28/53 (B) July 23, 1953

"Spectrophotometric curves and Munsell notations are requested on samples of film (2-1/4 x 2-1/4 inches) whose purpose and function are more or less explained on the tabulation sheet herewith. Film numbers W-132 to W-236 are sent herewith with tabulation sheet. In a sense when these curves have been made, it will enable a series of comparisons to be made of many

of the factors involved in this study on the principle of solving for a series of simultaneous equations."

"To test color fidelity over: 1. A range of underexposure and overexposure of seven types of color reversal film; 2. The possibility of making suitable filters by overexposure, i.e., securing in this convenient and inexpensive way, a filter sufficiently thin but really exactly representing on any particular film used, objects of military importance; 3. When such a filter exactly representing a military object is compared with a similarly prepared filter for any of the various backgrounds, the following can be deduced with fair accuracy: a) degree of contrast between object and background on the seven types of films studied, b) a filter can be plotted that will best serve to give maximum contrast between object and background when used in photographing such a pair on any kind of photographic film studied, and c) a similar filter or filtering system can be planned that will give the maximum contrast between the background and the military object showing on a color transparency when this filter is interposed between the eye of the observer and transparency or between the source of light and the transparency."

"Note: The Project Director would like to have these films for further study at some later date."

* * * *

Serial Number 2.1 WADC-35/55 April 20, 1955

"Spectrophotometric curves on color transparencies of wet and dry sand and gravel, W-872 to W-946 (not complete). Total: 51 transparencies

* * * *

Serial Number 2.1 WADC-42/56 March 3, 1956

"Spectrophotometry of bark specimens, 400 to 1080 millimicrons. Two samples of tree bark: Scrub pine (pinus virginiana, Mill.) and White Oak (Quercus alba, L.). Measure inner and outer sides of tree bark specimens.

* * * *

Appendix B

Tables of Spectrophotometric Data

Tables of visible and near-infrared spectral directional reflectance (400 to 1080 millimicrons) of eleven samples of natural objects; such as sand, soil, and the barks of trees.

Tables of the visible spectral transmittance (400 to 750 millimicrons) of eighty-five samples of color transparencies of natural objects; such as sky, clouds, water, green vegetation, wet sand, dry sand, and wet gravel.

Values of spectral directional reflectance or of spectral transmittance were read at 10 millimicron intervals from the original copies of the 21 recordings shown in Appendix C. For the overlapping segments of the region 730 to 750 millimicrons, on the reflectance measurements, an average of both determinations in each case is reported.

Reflecting Natural Objects

Spectral Directional Reflectance of the Indicated Wet Sands and Soil for the Visible and Near Infrared Spectrum, 400 to 1080 millimicrons. (See Appendix C, GE Graph Sheets Serial No. GE II-1393 and -1394.)

(1) Wet White Sand (Rodger's Quarry)				(2) Wet Yellowish Quartz Sand (Rodger's Quarry)				(3) Wet Commercial (Zonalite) "Vermiculite"			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.118	750	0.294	400	0.086	750	0.332	400	0.101	750	0.247
10	.124	60	.299	10	.090	60	.335	10	.105	60	.252
20	.128	70	.300	20	.093	70	.336	20	.107	70	.254
30	.135	80	.301	30	.100	80	.336	30	.110	80	.257
40	.142	90	.302	40	.108	90	.336	40	.114	90	.259
450	.150	800	.302	450	.113	800	.336	450	.118	800	.260
60	.152	10	.303	60	.115	10	.335	60	.122	10	.262
70	.154	20	.303	70	.116	20	.334	70	.126	20	.263
80	.157	30	.304	80	.119	30	.332	80	.128	30	.264
90	.162	40	.304	90	.125	40	.330	90	.130	40	.264
500	.168	850	.303	500	.133	850	.327	500	.133	850	.265
10	.176	60	.303	10	.143	60	.326	10	.136	60	.265
20	.185	70	.304	20	.154	70	.324	20	.141	70	.265
30	.196	80	.304	30	.167	80	.323	30	.147	80	.264
40	.206	90	.304	40	.182	90	.322	40	.154	90	.264
550	.216	900	.304	550	.200	900	.322	550	.161	900	.263
60	.226	10	.304	60	.219	10	.321	60	.168	10	.263
70	.236	20	.305	70	.236	20	.320	70	.174	20	.263
80	.242	30	.305	80	.252	30	.320	80	.180	30	.262
90	.248	40	.304	90	.262	40	.320	90	.184	40	.261
600	.252	950	.302	600	.270	950	.318	600	.190	950	.260
10	.256	60	.300	10	.276	60	.316	10	.194	60	.256
20	.258	70	.300	20	.280	70	.315	20	.196	70	.256
30	.260	80	.300	30	.282	80	.316	30	.200	80	.256
40	.262	90	.302	40	.284	90	.320	40	.204	90	.256
650	.266	1000	.306	650	.288	1000	.323	650	.208	1000	.257
60	.268	10	.308	60	.290	10	.326	60	.212	10	.260
70	.270	20	.310	70	.294	20	.331	70	.216	20	.261
80	.274	30	.314	80	.299	30	.334	80	.220	30	.262
90	.276	40	.316	90	.304	40	.337	90	.224	40	.262
700	.280	1050	.318	700	.309	1050	.340	700	.227	1050	.264
10	.282	60	.318	10	.314	60	.344	10	.231	60	.264
20	.285	70	.320	20	.320	70	.347	20	.235	70	.264
30	.291	80	.320	30	.325	80	.349	30	.241	80	.264
40	.293			40	.328			40	.244		

Reflecting Natural Objects

Spectral Directional Reflectance of the Indicated Dry Sands and Soil for the Visible and Near Infrared Spectrum, 400 to 1080 millimicrons. (See Appendix C, GE Graph Sheets Serial No. GE II-1391 and -1392.)

(4) Dry White Sand (Rodger's Quarry)

Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.230	750	0.479
10	.238	60	.481
20	.246	70	.483
30	.257	80	.485
40	.268	90	.486
450	.278	800	.487
60	.284	10	.488
70	.287	20	.489
80	.292	30	.490
90	.300	40	.490
500	.310	850	.491
10	.322	60	.492
20	.332	70	.492
30	.346	80	.493
40	.360	90	.494
550	.374	900	.496
60	.386	10	.496
70	.400	20	.498
80	.409	30	.500
90	.416	40	.500
600	.422	950	.502
10	.427	60	.504
20	.431	70	.506
30	.435	80	.508
40	.438	90	.510
650	.442	1000	.513
60	.445	10	.515
70	.450	20	.516
80	.453	30	.518
90	.458	40	.520
700	.462	1050	.522
10	.466	60	.525
20	.470	70	.525
30	.474	80	.527
40	.476		

(5) Dry Yellowish Quartz Sand (Rodger's Quarry)

Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.176	750	0.527
10	.183	60	.530
20	.191	70	.532
30	.205	80	.534
40	.219	90	.535
450	.228	800	.535
60	.232	10	.534
70	.236	20	.533
80	.240	30	.532
90	.250	40	.530
500	.264	850	.530
10	.280	60	.528
20	.296	70	.527
30	.316	80	.526
40	.336	90	.526
550	.360	900	.526
60	.383	10	.527
70	.405	20	.528
80	.423	30	.530
90	.438	40	.531
600	.448	950	.533
10	.454	60	.535
20	.459	70	.537
30	.463	80	.540
40	.466	90	.543
650	.471	1000	.545
60	.475	10	.550
70	.480	20	.552
80	.486	30	.555
90	.492	40	.558
700	.500	1050	.561
10	.506	60	.564
20	.512	70	.568
30	.518	80	.570
40	.524		

(6) Dry Commercial (Zonalite) "Vermiculite"

Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.204	750	0.36[illegible]
10	.208	60	.36[illegible]
20	.212	70	.36[illegible]
30	.216	80	.37[illegible]
40	.222	90	.37[illegible]
450	.226	800	.37[illegible]
60	.232	10	.37[illegible]
70	.236	20	.37[illegible]
80	.238	30	.37[illegible]
90	.240	40	.37[illegible]
500	.244	850	.38[illegible]
10	.248	60	.38[illegible]
20	.253	70	.38[illegible]
30	.260	80	.38[illegible]
40	.266	90	.38[illegible]
550	.274	900	.38[illegible]
60	.281	10	.38[illegible]
70	.288	20	.38[illegible]
80	.293	30	.38[illegible]
90	.298	40	.38[illegible]
600	.302	950	.38[illegible]
10	.306	60	.38[illegible]
20	.310	70	.38[illegible]
30	.314	80	.38[illegible]
40	.318	90	.38[illegible]
650	.322	1000	.38[illegible]
60	.326	10	.38[illegible]
70	.330	20	.38[illegible]
80	.333	30	.38[illegible]
90	.336	40	.38[illegible]
700	.340	1050	.38[illegible]
10	.345	60	.38[illegible]
20	.349	70	.38[illegible]
30	.354	80	.38[illegible]
40	.357		

Reflecting Natural Objects

Spectral Directional Reflectance of the Indicated Damp Soil for the Visible and Near Infrared Spectrum, 400 to 1080 millimicrons. (See Appendix C, GE Graph Sheets Serial No. GE II-1395 and -1396.)

(7) Damp Collington Sandy Loam

Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.100	750	0.210
10	.101	60	.212
20	.103	70	.214
30	.106	80	.216
40	.109	90	.216
450	.111	800	.218
60	.113	10	.220
70	.114	20	.220
80	.116	30	.221
90	.118	40	.222
500	.122	850	.222
10	.126	60	.222
20	.130	70	.223
30	.135	80	.224
40	.141	90	.224
550	.147	900	.224
60	.152	10	.225
70	.158	20	.226
80	.162	30	.226
90	.166	40	.226
600	.168	950	.228
10	.170	60	.228
20	.172	70	.229
30	.175	80	.230
40	.177	90	.231
650	.180	1000	.232
60	.182	10	.233
70	.185	20	.235
80	.188	30	.236
90	.192	40	.236
700	.196	1050	.238
10	.199	60	.238
20	.201	70	.240
30	.205	80	.240
40	.207		

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Sky, Clouds, Water, and Seaweed on Ansco Daylight Color Film or Special Ansco Blue and Red Sensitive Film. (See Table I and Appendix C, GE Graph Sheets Serial No. GE II-1577 and -1583.)

Wave length mμ	Sample Numbers										
	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
400	0.071	0.106	0.355	0.094	0.036	0.026	0.045	0.072	0.217	0.286	0.094
10	.072	.110	.412	.097	.035	.024	.042	.072	.253	.339	.113
20	.066	.103	.458	.091	.029	.024	.035	.065	.274	.377	.136
30	.059	.095	.489	.083	.024	.015	.029	.057	.287	.406	.143
40	.054	.088	.517	.077	.025	.012	.025	.052	.301	.433	.157
450	.060	.097	.547	.085	.022	.013	.028	.058	.328	.469	.171
60	.073	.115	.573	.102	.030	.018	.037	.073	.363	.500	.196
70	.086	.134	.591	.121	.040	.026	.050	.094	.401	.533	.236
80	.090	.142	.601	.130	.048	.033	.063	.112	.422	.552	.284
90	.080	.134	.604	.123	.040	.033	.067	.117	.428	.563	.323
500	.061	.112	.594	.103	.037	.026	.061	.107	.412	.554	.338
10	.042	.086	.574	.080	.026	.019	.048	.091	.385	.534	.327
20	.030	.068	.571	.063	.018	.014	.038	.076	.365	.528	.293
30	.022	.056	.575	.052	.014	.010	.031	.067	.351	.525	.243
40	.019	.050	.569	.045	.010	.008	.028	.062	.337	.515	.186
550	.017	.048	.566	.044	.010	.006	.026	.062	.332	.510	.133
60	.018	.050	.561	.046	.010	.006	.029	.066	.331	.504	.088
70	.020	.055	.551	.051	.012	.008	.033	.074	.330	.496	.056
80	.022	.060	.537	.056	.013	.008	.036	.081	.327	.482	.034
90	.021	.064	.519	.059	.014	.009	.039	.086	.318	.465	.018
600	.020	.063	.499	.058	.013	.008	.039	.087	.305	.441	.010
10	.018	.060	.478	.056	.012	.007	.038	.085	.291	.426	.006
20	.016	.056	.464	.052	.010	.006	.035	.081	.278	.413	.002
30	.014	.052	.454	.048	.008	.005	.033	.079	.270	.404	.000
40	.014	.050	.446	.046	.008	.004	.031	.078	.265	.400	.000
650	.014	.050	.443	.046	.008	.004	.032	.080	.266	.399	.000
60	.014	.054	.446	.050	.009	.006	.034	.086	.272	.404	.000
70	.017	.060	.454	.056	.012	.008	.040	.096	.286	.418	.000
80	.022	.070	.469	.066	.016	.011	.050	.112	.308	.439	.004
90	.032	.089	.493	.083	.024	.017	.064	.137	.340	.469	.006
700	.046	.116	.524	.109	.036	.028	.087	.172	.381	.506	.013
10	.070	.152	.558	.145	.055	.045	.120	.219	.431	.549	.024
20	.105	.201	.598	.195	.087	.074	.165	.276	.485	.594	.042
30	.155	.263	.636	.253	.132	.114	.223	.340	.541	.640	.072
40	.214	.324	.670	.315	.182	.165	.286	.406	.592	.678	.111
750	.279	.393	.702	.382	.246	.224	.351	.474	.641	.714	.162

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Sky, Clouds, and Green and Yellow Leaves of Trees of Ansco Daylight Color Film or Special Ansco Blue and Red Sensitive Film. (See Table I and Appendix C, GE Graph Sheets Serial No. GE II-1578, -1579, -1583, and -1749.)

Wave length mμ	Sample Numbers										
	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
400	0.304	0.421	0.042	0.140	0.240	0.006	0.009	0.009	0.024	0.022	0.016
10	.368	.500	.052	.196	.318	.003	.008	.008	.022	.020	.014
20	.415	.552	.058	.251	.384	.000	.005	.005	.018	.016	.011
30	.450	.588	.061	.297	.444	.000	.002	.002	.014	.013	.009
40	.476	.618	.063	.332	.487	.000	.000	.000	.012	.012	.008
450	.501	.642	.069	.360	.518	.000	.001	.001	.014	.012	.009
60	.529	.666	.084	.386	.544	.000	.005	.005	.019	.018	.012
70	.564	.690	.114	.410	.566	.005	.010	.010	.029	.028	.018
80	.597	.710	.156	.424	.577	.011	.019	.019	.043	.037	.026
90	.620	.722	.197	.420	.573	.019	.029	.027	.055	.042	.030
500	.628	.727	.224	.396	.552	.025	.034	.030	.059	.040	.029
10	.621	.726	.226	.354	.515	.027	.032	.027	.054	.033	.023
20	.598	.717	.204	.294	.465	.026	.028	.022	.047	.026	.018
30	.566	.700	.165	.232	.401	.024	.024	.018	.040	.021	.014
40	.522	.677	.121	.168	.337	.022	.020	.016	.035	.018	.012
550	.470	.646	.080	.115	.269	.022	.019	.014	.032	.016	.011
60	.413	.613	.048	.072	.204	.022	.019	.014	.031	.016	.010
70	.359	.567	.026	.044	.155	.023	.019	.014	.030	.016	.010
80	.305	.539	.014	.024	.110	.024	.019	.013	.030	.017	.010
90	.261	.502	.006	.012	.078	.024	.018	.012	.030	.016	.010
600	.218	.466	.000	.006	.055	.022	.016	.010	.026	.015	.009
10	.186	.435	.000	.002	.040	.020	.014	.008	.022	.014	.008
20	.161	.411	.000	.000	.029	.018	.011	.006	.018	.012	.006
30	.144	.394	.000	.000	.023	.016	.009	.004	.016	.010	.004
40	.133	.383	.000	.000	.020	.014	.008	.004	.014	.010	.004
650	.128	.377	.000	.000	.020	.014	.008	.004	.014	.010	.004
60	.129	.379	.000	.000	.020	.015	.009	.004	.015	.010	.004
70	.138	.389	.000	.000	.024	.018	.011	.006	.018	.012	.006
80	.151	.406	.000	.000	.028	.022	.015	.009	.022	.014	.009
90	.174	.434	.000	.003	.038	.030	.022	.014	.030	.020	.012
700	.206	.469	.004	.008	.054	.042	.035	.024	.044	.030	.020
10	.250	.516	.010	.016	.080	.062	.054	.040	.066	.046	.033
20	.303	.557	.020	.030	.116	.093	.086	.064	.100	.071	.054
30	.365	.605	.041	.056	.164	.135	.131	.103	.144	.106	.086
40	.428	.649	.070	.091	.224	.190	.186	.153	.200	.155	.131
750	.492	.690	.112	.140	.288	.253	.252	.216	.268	.216	.187

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Green and Yellow Leaves of Trees and Green Vegetation on Special Ansco Green and Blue Sensitive Film and Special Ansco Blue and Red Sensitive Film. (See Table I and Appendix C, GE Graph Sheet Serial No. GE II-1582.)

Wave length mμ	Sample Numbers										
	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(4
400	0.000	0.000	0.019	0.019	0.040	0.035	0.016	0.012	0.040	0.032	0.076	0.0
10	.000	.000	.011	.011	.029	.026	.016	.012	.047	.036	.091	.0
20	.000	.000	.006	.006	.019	.017	.016	.012	.048	.036	.096	.0
30	.000	.000	.002	.002	.012	.012	.015	.011	.047	.036	.099	.0
40	.000	.000	.000	.000	.010	.010	.014	.012	.047	.036	.101	.0
450	.000	.000	.000	.000	.010	.010	.015	.012	.051	.039	.109	.1
60	.000	.000	.002	.002	.014	.013	.020	.015	.064	.049	.128	.1
70	.000	.000	.006	.006	.022	.018	.034	.024	.092	.070	.166	.1
80	.000	.000	.011	.010	.032	.025	.060	.042	.132	.106	.217	.1
90	.000	.000	.016	.010	.041	.028	.100	.076	.184	.156	.268	.2
500	.000	.000	.016	.010	.044	.030	.142	.120	.225	.196	.305	.2
10	.000	.000	.014	.010	.041	.027	.175	.156	.244	.221	.317	.3
20	.000	.000	.013	.008	.038	.024	.179	.170	.235	.218	.302	.3
30	.000	.000	.013	.008	.038	.022	.161	.158	.205	.191	.268	.2
40	.000	.000	.014	.009	.040	.022	.128	.128	.162	.152	.224	.2
550	.000	.000	.018	.012	.048	.026	.090	.092	.117	.109	.173	.1
60	.004	.000	.027	.018	.063	.035	.058	.060	.078	.072	.136	.1
70	.008	.000	.043	.030	.088	.050	.034	.037	.052	.042	.096	.0
80	.013	.004	.072	.052	.128	.080	.020	.020	.032	.026	.069	.0
90	.022	.007	.116	.089	.188	.123	.010	.010	.020	.016	.050	.0
600	.036	.012	.174	.137	.253	.175	.004	.005	.012	.009	.037	.0
10	.054	.018	.238	.194	.324	.238	.000	.001	.008	.005	.028	.0
20	.074	.026	.305	.259	.395	.305	.000	.000	.005	.001	.022	.0
30	.094	.032	.370	.325	.458	.370	.000	.000	.002	.000	.019	.0
40	.116	.041	.432	.386	.518	.433	.000	.000	.001	.000	.016	.0
650	.136	.050	.498	.452	.575	.498	.000	.000	.001	.000	.016	.0
60	.155	.057	.552	.515	.626	.552	.000	.000	.001	.000	.016	.0
70	.176	.066	.611	.573	.671	.611	.000	.000	.002	.000	.018	.0
80	.196	.072	.657	.624	.710	.657	.000	.000	.005	.002	.021	.0
90	.212	.078	.700	.671	.744	.700	.000	.002	.007	.005	.026	.0
700	.230	.085	.737	.714	.772	.737	.006	.007	.013	.010	.036	.0
10	.243	.090	.767	.748	.795	.767	.014	.016	.023	.020	.050	.0
20	.255	.096	.791	.775	.814	.791	.026	.030	.040	.035	.073	.0
30	.266	.100	.810	.797	.830	.810	.050	.055	.066	.060	.107	.1
40	.275	.104	.824	.814	.838	.824	.084	.091	.103	.097	.149	.1
750	.281	.106	.834	.825	.847	.834	.128	.142	.152	.145	.198	.1

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Wet Sand on Ansco Daylight Color Film and Special Ansco Red and Green Sensitive Film. (See Table I and Appendix C, GE Graph Sheets Serial No. GE II-1567 and -1568.)

Wave length mμ	Sample Numbers (42)	(43)	(44)	(45)	(46)	(47)
400	0.004	0.015	0.036	0.115	0.167	0.232
10	.002	.015	.039	.158	.221	.293
20	.000	.013	.037	.202	.272	.349
30	.000	.010	.034	.240	.316	.400
40	.000	.010	.034	.270	.351	.442
450	.000	.011	.039	.306	.396	.490
60	.002	.016	.050	.335	.430	.525
70	.006	.026	.069	.331	.435	.538
80	.010	.038	.091	.298	.409	.527
90	.014	.049	.111	.246	.362	.497
500	.016	.054	.120	.191	.308	.455
10	.014	.050	.115	.138	.248	.401
20	.012	.046	.109	.100	.203	.359
30	.012	.044	.104	.074	.167	.324
40	.011	.044	.101	.054	.136	.291
550	.012	.046	.106	.039	.114	.264
60	.014	.052	.116	.028	.096	.241
70	.018	.062	.130	.021	.081	.218
80	.024	.074	.148	.014	.066	.196
90	.029	.087	.164	.010	.053	.174
600	.034	.096	.176	.006	.041	.151
10	.037	.102	.182	.002	.032	.132
20	.038	.106	.186	.000	.026	.118
30	.040	.109	.190	.000	.022	.108
40	.041	.112	.194	.000	.020	.100
650	.044	.119	.201	.000	.020	.100
60	.050	.127	.212	.000	.021	.102
70	.057	.141	.230	.000	.024	.112
80	.069	.161	.252	.004	.030	.126
90	.086	.189	.285	.006	.041	.150
700	.114	.226	.326	.014	.058	.181
10	.149	.274	.375	.025	.084	.225
20	.194	.326	.430	.044	.119	.279
30	.249	.384	.485	.072	.165	.339
40	.308	.444	.537	.113	.220	.397
750	.373	.502	.589	.166	.285	.464

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Wet Sand on Special Ansco Green and Blue Sensitive Film and Special Ansco Blue and Red Sensitive Film. (See Table I and Appendix C, GE Graph Sheet Serial No. GE II-1568.)

Wave length mμ	Sample Numbers					
	(48)	(49)	(50)	(51)	(52)	(53)
400	0.002	0.013	0.041	0.022	0.052	0.110
10	.000	.006	.032	.021	.051	.116
20	.000	.003	.022	.018	.047	.115
30	.000	.000	.016	.016	.043	.112
40	.000	.000	.014	.015	.042	.114
450	.000	.000	.016	.017	.046	.124
60	.000	.001	.023	.025	.060	.149
70	.000	.006	.035	.044	.091	.198
80	.003	.014	.052	.081	.145	.267
90	.008	.022	.069	.142	.224	.357
500	.010	.027	.079	.215	.314	.441
10	.010	.028	.080	.281	.391	.512
20	.011	.028	.077	.319	.441	.558
30	.012	.029	.077	.322	.462	.580
40	.014	.033	.081	.306	.463	.580
550	.019	.041	.095	.267	.438	.564
60	.029	.058	.121	.221	.400	.536
70	.048	.084	.160	.177	.358	.506
80	.079	.129	.219	.138	.316	.474
90	.127	.186	.292	.105	.275	.441
600	.189	.260	.371	.080	.238	.406
10	.258	.337	.446	.061	.209	.378
20	.326	.409	.513	.050	.186	.356
30	.394	.475	.571	.041	.170	.340
40	.456	.534	.621	.036	.159	.329
650	.519	.590	.668	.034	.154	.321
60	.574	.638	.705	.035	.154	.320
70	.624	.680	.738	.039	.161	.329
80	.666	.714	.764	.046	.176	.345
90	.705	.744	.786	.058	.199	.371
700	.736	.770	.805	.076	.230	.405
10	.762	.789	.820	.105	.271	.448
20	.781	.804	.829	.146	.324	.495
30	.795	.813	.838	.194	.380	.543
40	.807	.823	.842	.251	.440	.590
750	.816	.829	.847	.319	.500	.636

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Wet Sand on Special Ansco Red Sensitive Film and Special Ansco Green Sensitive Film. (See Table I and Appendix C, GE Graph Sheet Serial No. GE II-1569.)

Wave length mμ	Sample Numbers					
	(54)	(55)	(56)	(57)	(58)	(59)
400	0.160	0.175	0.237	0.339	0.403	0.468
10	.240	.255	.324	.316	.394	.470
20	.336	.352	.417	.287	.381	.468
30	.432	.457	.510	.257	.366	.464
40	.511	.538	.586	.237	.357	.466
450	.559	.592	.642	.252	.379	.491
60	.577	.615	.668	.276	.407	.519
70	.566	.608	.672	.271	.409	.526
80	.532	.576	.654	.236	.380	.506
90	.480	.524	.620	.186	.330	.467
500	.417	.460	.571	.136	.275	.420
10	.341	.381	.506	.099	.223	.370
20	.263	.300	.436	.078	.191	.339
30	.188	.220	.360	.068	.175	.325
40	.125	.153	.287	.066	.171	.320
550	.074	.094	.216	.074	.183	.334
60	.040	.056	.159	.093	.214	.366
70	.019	.030	.114	.126	.259	.415
80	.008	.015	.079	.176	.320	.472
90	.001	.008	.054	.238	.390	.532
600	.000	.001	.038	.310	.464	.590
10	.000	.000	.027	.380	.528	.640
20	.000	.000	.020	.450	.582	.680
30	.000	.000	.016	.509	.631	.715
40	.000	.000	.014	.561	.674	.745
650	.000	.000	.013	.616	.707	.770
60	.000	.000	.014	.659	.740	.789
70	.000	.000	.016	.694	.770	.809
80	.000	.000	.020	.726	.786	.826
90	.000	.000	.026	.758	.805	.837
700	.000	.004	.038	.778	.825	.845
10	.004	.010	.055	.791	.835	.854
20	.013	.021	.088	.808	.839	.862
30	.029	.040	.120	.820	.845	.864
40	.054	.069	.166	.825	.854	.864
750	.093	.115	.224	.828	.858	.868

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Wet Sand on Special Ansco Blue Sensitive Film and Special Ansco Plenacolor Film. (See Table I and Appendix C, GE Graph Sheets Serial No. GE II-1567 and -1569.)

Wave length mμ	Sample Numbers (60)	(61)	(62)	(63)	(64)	(65)
400	0.013	0.023	0.055	0.019	0.012	0.006
10	.006	.015	.045	.026	.016	.008
20	.002	.009	.034	.032	.019	.009
30	.000	.006	.026	.039	.023	.010
40	.000	.004	.024	.046	.027	.012
450	.000	.004	.025	.058	.035	.016
60	.001	.008	.033	.073	.045	.023
70	.008	.019	.057	.089	.056	.030
80	.026	.048	.105	.100	.065	.036
90	.072	.109	.189	.104	.068	.036
500	.158	.207	.300	.097	.063	.033
10	.280	.339	.423	.084	.052	.026
20	.410	.461	.534	.075	.046	.021
30	.524	.566	.617	.070	.041	.018
40	.606	.638	.674	.062	.036	.016
550	.666	.690	.712	.056	.032	.014
60	.704	.724	.740	.050	.028	.012
70	.731	.749	.756	.044	.024	.011
80	.752	.767	.773	.038	.021	.010
90	.772	.784	.784	.031	.017	.008
600	.788	.799	.798	.026	.014	.006
10	.800	.809	.811	.020	.010	.003
20	.814	.821	.821	.016	.006	.001
30	.819	.830	.830	.012	.004	.000
40	.832	.839	.834	.010	.002	.000
650	.835	.842	.844	.008	.002	.000
60	.840	.850	.850	.008	.000	.000
70	.851	.855	.852	.007	.000	.000
80	.850	.858	.861	.008	.000	.000
90	.856	.866	.864	.008	.001	.000
700	.865	.869	.867	.010	.002	.000
10	.862	.870	.875	.014	.005	.000
20	.869	.878	.875	.020	.009	.002
30	.875	.877	.875	.030	.016	.006
40	.872	.878	.880	.045	.026	.014
750	.872	.882	.884	.068	.044	.026

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Dry Sand on Ansco Daylight Color Film and Special Ansco Red and Green Sensitive Film. (See Table I and Appendix C, GE Graph Sheets Serial No. GE II-1570 and -1571.)

Wave length mμ	Sample Numbers (66)	(67)	(68)	(69)	(70)	(71)
400	0.011	0.025	0.055	0.135	0.202	0.261
10	.010	.024	.061	.184	.262	.326
20	.008	.021	.062	.234	.321	.388
30	.006	.018	.060	.277	.371	.444
40	.004	.017	.061	.315	.416	.494
450	.006	.019	.070	.358	.463	.543
60	.009	.028	.090	.389	.498	.580
70	.016	.042	.117	.388	.507	.600
80	.025	.060	.154	.356	.488	.597
90	.033	.075	.168	.302	.449	.578
500	.034	.079	.169	.241	.396	.546
10	.030	.072	.157	.179	.332	.501
20	.026	.064	.145	.132	.282	.465
30	.024	.060	.136	.099	.240	.433
40	.022	.057	.129	.074	.204	.397
550	.024	.058	.131	.054	.174	.366
60	.027	.065	.141	.040	.147	.338
70	.034	.076	.156	.030	.126	.310
80	.041	.089	.174	.020	.104	.281
90	.050	.102	.188	.014	.086	.251
600	.054	.112	.198	.009	.069	.223
10	.058	.117	.202	.006	.054	.199
20	.059	.119	.205	.002	.045	.179
30	.060	.120	.207	.001	.038	.164
40	.060	.123	.209	.000	.034	.156
650	.063	.127	.214	.000	.033	.151
60	.068	.135	.224	.000	.034	.155
70	.078	.149	.240	.002	.039	.164
80	.091	.168	.263	.004	.048	.182
90	.113	.195	.294	.009	.062	.209
700	.143	.235	.338	.016	.084	.246
10	.185	.283	.385	.028	.114	.294
20	.240	.344	.443	.050	.159	.351
30	.298	.403	.500	.081	.213	.414
40	.364	.464	.553	.123	.272	.474
750	.431	.524	.604	.178	.342	.534

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Dry Sand on Special Ansco Green and Blue Sensitive Film and Special Ansco Blue and Red Sensitive Film. (See Table I and Appendix C, GE Graph Sheet Serial No. GE II-1571.)

Wave length mμ	Sample Numbers (72)	(73)	(74)	(75)	(76)	(77)
400	0.030	0.062	0.120	0.076	0.141	0.252
10	.021	.050	.109	.080	.159	.298
20	.014	.038	.094	.076	.166	.329
30	.010	.029	.080	.072	.169	.352
40	.008	.026	.074	.073	.176	.376
450	.009	.028	.081	.081	.195	.407
60	.014	.039	.102	.101	.229	.451
70	.023	.057	.130	.149	.290	.507
80	.036	.079	.162	.220	.370	.566
90	.050	.099	.182	.310	.456	.623
500	.055	.105	.185	.394	.524	.660
10	.053	.101	.174	.465	.579	.688
20	.050	.096	.164	.501	.607	.700
30	.050	.095	.159	.510	.612	.699
40	.054	.100	.164	.494	.601	.688
550	.064	.115	.181	.460	.575	.669
60	.084	.144	.216	.415	.541	.645
70	.119	.186	.265	.369	.505	.621
80	.172	.248	.331	.322	.467	.594
90	.239	.322	.406	.276	.426	.566
600	.318	.401	.481	.237	.391	.539
10	.394	.473	.546	.204	.360	.516
20	.464	.540	.604	.180	.336	.500
30	.528	.596	.650	.160	.318	.490
40	.582	.642	.691	.150	.305	.482
650	.634	.688	.726	.142	.298	.476
60	.678	.724	.756	.142	.298	.480
70	.716	.754	.780	.150	.308	.488
80	.747	.778	.800	.164	.324	.504
90	.771	.799	.817	.188	.352	.529
700	.793	.815	.830	.220	.389	.560
10	.809	.827	.839	.266	.435	.595
20	.821	.837	.847	.320	.487	.634
30	.828	.845	.854	.379	.539	.672
40	.835	.847	.855	.444	.587	.707
750	.840	.851	.858	.504	.634	.735

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Dry Sand on Special Ansco Red Sensitive Film and Special Ansco Green Sensitive Film. (See Table I and Appendix C, GE Graph Sheet Serial No. GE II-1572.)

Wave length mμ	Sample Numbers (78)	(79)	(80)	(81)	(82)	(83)
400	0.161	0.248	0.248	0.451	0.518	0.528
10	.247	.338	.338	.451	.526	.554
20	.348	.438	.438	.447	.541	.578
30	.453	.531	.531	.438	.549	.603
40	.538	.608	.608	.438	.561	.629
450	.592	.658	.658	.462	.588	.658
60	.609	.681	.681	.492	.617	.688
70	.596	.676	.680	.496	.626	.706
80	.555	.650	.657	.467	.617	.713
90	.501	.606	.619	.421	.591	.713
500	.432	.551	.566	.363	.552	.701
10	.351	.480	.497	.309	.514	.683
20	.270	.405	.426	.273	.490	.684
30	.194	.326	.346	.255	.478	.691
40	.125	.246	.269	.250	.476	.696
550	.074	.176	.197	.264	.493	.711
60	.040	.120	.136	.299	.525	.730
70	.019	.078	.092	.349	.566	.746
80	.008	.047	.059	.413	.613	.766
90	.001	.028	.036	.484	.661	.785
600	.000	.016	.022	.549	.700	.799
10	.000	.010	.014	.605	.734	.812
20	.000	.005	.008	.658	.764	.824
30	.000	.002	.006	.697	.785	.832
40	.000	.001	.004	.727	.800	.840
650	.000	.000	.002	.760	.816	.848
60	.000	.000	.003	.782	.832	.852
70	.000	.001	.004	.798	.840	.856
80	.000	.004	.006	.815	.846	.862
90	.000	.008	.010	.834	.859	.869
700	.000	.014	.018	.842	.866	.870
10	.000	.024	.030	.846	.866	.874
20	.008	.043	.050	.856	.869	.881
30	.020	.071	.080	.864	.876	.879
40	.041	.111	.113	.865	.876	.879
750	.076	.165	.178	.863	.876	.880

Color Transparencies of Natural Objects

Spectral Transmittance of Color Transparencies of Dry Sand and Wet Gravel on Special Ansco Blue Sensitive Film, Special Ansco Plenacolor Film, and Ansco Daylight Color Film. (See Table I and Appendix C, GE Graph Sheets Serial No GE II-1570, -1572, and -1573.)

Wave length mμ	Sample Numbers (84)	(85)	(86)	(87)	(88)	(89)	(90)	(91)	(9
400	0.035	0.084	0.202	0.006	0.001	0.000	0.047	0.082	0.1
10	.026	.070	.197	.008	.002	.000	.052	.099	.1
20	.017	.055	.183	.008	.002	.000	.052	.106	.1
30	.012	.045	.171	.010	.003	.001	.050	.110	.2
40	.010	.041	.169	.011	.004	.000	.050	.116	.2
450	.010	.044	.181	.014	.006	.000	.056	.133	.2
60	.018	.059	.214	.021	.009	.002	.070	.160	.3
70	.036	.097	.276	.029	.014	.006	.092	.194	.3
80	.080	.169	.367	.036	.018	.009	.115	.224	.3
90	.160	.270	.466	.038	.019	.010	.127	.238	.4
500	.272	.387	.557	.034	.016	.008	.125	.233	.4
10	.400	.501	.634	.027	.012	.004	.112	.214	.3
20	.512	.593	.690	.022	.009	.003	.099	.196	.3
30	.601	.662	.729	.019	.008	.001	.089	.184	.3
40	.665	.710	.755	.016	.006	.000	.084	.174	.3
550	.708	.741	.770	.015	.006	.000	.084	.172	.3
60	.736	.762	.782	.014	.005	.000	.090	.180	.3
70	.755	.777	.789	.013	.005	.000	.100	.191	.3
80	.771	.789	.799	.012	.004	.000	.112	.205	.3
90	.786	.801	.807	.010	.004	.000	.124	.216	.3
600	.799	.810	.816	.008	.002	.000	.130	.221	.3
10	.812	.823	.825	.006	.001	.000	.133	.222	.3
20	.821	.829	.831	.003	.000	.000	.133	.220	.3
30	.828	.839	.841	.000	.000	.000	.133	.220	.3
40	.838	.844	.844	.000	.000	.000	.134	.220	.3
650	.842	.848	.850	.000	.000	.000	.138	.225	.3
60	.849	.852	.857	.000	.000	.000	.146	.234	.3
70	.856	.856	.856	.000	.000	.000	.158	.250	.3
80	.856	.862	.862	.000	.000	.000	.179	.274	.3
90	.864	.868	.870	.000	.000	.000	.208	.307	.4
700	.870	.870	.871	.000	.000	.000	.248	.349	.4
10	.870	.874	.876	.000	.000	.000	.295	.399	.5
20	.877	.878	.880	.004	.000	.000	.352	.455	.5
30	.879	.879	.879	.008	.004	.000	.415	.513	.6
40	.879	.880	.881	.017	.009	.005	.474	.564	.6
750	.880	.884	.887	.030	.020	.014	.534	.616	.6

Reflecting Natural Objects

Spectral Directional Reflectance of the Outer Bark and Inner Bark of Scrub Pine (Pinus virginiana, Mill.) for the Visible and Near Infrared Spectrum, 400 to 1080 millimicrons. (See Appendix C, GE Graph Sheets Serial No. GE II 1736 and -1737.)

(93) Outer Bark, Scrub Pine (Pinus virginiana, Mill.)

Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.072	750	0.252
10	.075	60	.260
20	.078	70	.269
30	.080	80	.277
40	.083	90	.286
450	.085	800	.295
60	.088	10	.304
70	.090	20	.314
80	.093	30	.322
90	.095	40	.330
500	.097	850	.338
10	.100	60	.346
20	.102	70	.354
30	.106	80	.362
40	.110	90	.370
550	.113	900	.377
60	.118	10	.385
70	.122	20	.393
80	.127	30	.400
90	.132	40	.406
600	.138	950	.412
10	.144	60	.418
20	.150	70	.423
30	.156	80	.428
40	.162	90	.434
650	.170	1000	.439
60	.178	10	.444
70	.185	20	.450
80	.193	30	.456
90	.200	40	.461
700	.209	1050	.468
10	.217	60	.470
20	.226	70	.477
30	.234	80	.480

(94) Inner Bark, Scrub Pine (Pinus virginiana, Mill.)

Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.075	750	0.468
10	.080	60	.496
20	.085	70	.524
30	.089	80	.550
40	.094	90	.577
450	.098	800	.600
60	.102	10	.622
70	.106	20	.642
80	.109	30	.662
90	.112	40	.682
500	.115	850	.698
10	.118	60	.715
20	.122	70	.730
30	.126	80	.745
40	.130	90	.759
550	.136	900	.772
60	.142	10	.783
70	.149	20	.792
80	.156	30	.802
90	.165	40	.812
600	.175	950	.819
10	.186	60	.824
20	.199	70	.827
30	.213	80	.829
40	.228	90	.830
650	.244	1000	.834
60	.261	10	.840
70	.278	20	.845
80	.298	30	.850
90	.318	40	.856
700	.339	1050	.861
10	.362	60	.866
20	.386	70	.868
30	.412	80	.870

Reflecting Natural Objects

Spectral Directional Reflectance of the Outer Bark and Inner Bark of White Oa (Quercus alba, L.) for the Visible and Near Infrared Spectrum, 400 to 1080 millimicrons. (See Appendix C, GE Graph Sheets Serial No. GE II-1736 and -17

(95) Outer Bark, White Oak (Quercus alba, L.)				(96) Inner Bark, White Oak (Quercus alba, L.)			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.186	750	0.376	400	0.043	750	0.135
10	.195	60	.383	10	.045	60	.138
20	.203	70	.390	20	.046	70	.142
30	.211	80	.398	30	.048	80	.145
40	.218	90	.405	40	.050	90	.150
450	.226	800	.412	450	.052	800	.154
60	.232	10	.420	60	.054	10	.157
70	.237	20	.426	70	.056	20	.162
80	.242	30	.433	80	.058	30	.166
90	.247	40	.439	90	.060	40	.170
500	.252	850	.444	500	.061	850	.174
10	.256	60	.450	10	.064	60	.178
20	.261	70	.456	20	.066	70	.182
30	.266	80	.461	30	.068	80	.186
40	.270	90	.467	40	.070	90	.190
550	.274	900	.472	550	.073	900	.195
60	.279	10	.478	60	.075	10	.198
70	.282	20	.484	70	.077	20	.202
80	.287	30	.490	80	.080	30	.206
90	.292	40	.496	90	.082	40	.210
600	.296	950	.500	600	.085	950	.213
10	.300	60	.505	10	.088	60	.216
20	.305	70	.510	20	.090	70	.219
30	.310	80	.515	30	.094	80	.222
40	.314	90	.520	40	.096	90	.225
650	.318	1000	.524	650	.100	1000	.228
60	.323	10	.529	60	.102	10	.235
70	.328	20	.534	70	.106	20	.234
80	.332	30	.539	80	.110	30	.237
90	.338	40	.544	90	.113	40	.240
700	.343	1050	.548	700	.116	1050	.242
10	.349	60	.554	10	.120	60	.245
20	.356	70	.559	20	.125	70	.247
30	.362	80	.564	30	.128	80	.250
40	.369			40	.131		

Appendix C

Ozalid Prints of Original Spectrophotometric Graph Sheets

Set of the Ozalid prints of the 21 original recordings of the visible and near infrared spectral directional reflectance of natural objects (400 to 1080 millimicrons), and the visible spectral transmittance of color transparencies of natural objects (400 to 750 millimicrons) made on a General Electric recording spectrophotometer. An index to the spectrophotometric curves of this set are listed in the following table, together with the dates of measurement. Note that the type of film used is also indicated in parenthesis following the description of the object of each color transparency. Exposure numbers W-132, W-133, W-134, and W-135 shown on GE graph sheet Serial No. GE II-1579 are of man-made objects and will be explained in NBS Report 4953.

Index to Appendix C

Part I. Reflecting Natural Objects

Sample Number	Description	GE Graph Sheet Serial No. and Date Measured: Visible Spectrum	GE Graph Sheet Serial No. and Date Measured: Near Infrared Spectrum	Curve Number
(1)	White Sand, Rodger's Quarry (Wet)	GE II-1393 2-17-54	GE II-1394	1
(2)	Yellowish Quartz Sand, Rodger's Quarry (Wet)	-1393 2-17-54	-1394	2
(3)	Commercial (Zonalite) "Vermiculite" (Wet)	-1393 2-17-54	-1394	3
(4)	White Sand, Rodger's Quarry (Dry)	-1391 2-17-54	-1392	1
(5)	Yellowish Quartz Sand, Rodger's Quarry (Dry)	-1391 2-17-54	-1392	2
(6)	Commercial (Zonalite) "Vermiculite" (Dry)	-1391 2-17-54	-1392	3
(7)	Collington Sandy Loam (Damp)	-1395 2-18-54	-1396	1
(93)	Bark, Outer, Scrub Pine (Pinus virginiana, Mill.)	-1736 8- 3-56	-1737	1
(94)	Bark, Inner, Scrub Pine (Pinus virginiana, Mill.)	-1736 8- 3-56	-1737	2
(95)	Bark, Outer, White Oak (Quercus alba, L.)	-1736 8- 3-56	-1737	3
(96)	Bark, Inner, White Oak (Quercus alba, L.)	-1736 8- 3-56	-1737	4

Index to Appendix C (continued)

Part II. Color Transparencies of Natural Objects

Sample Number	Exposure Number	Description	GE Graph Sheet Serial No. and Curve No.: Visible Spectrum	Curve Number	Da[te] Meas[ured]
(8)	W-68	Blue Sky (RGB)	GE II-1577	4	3-1
(9)	W-69	Gray Cloud (RGB)	-1577	5	3-1
(10)	W-70	Gray Sky, Thunderstorm Coming (to NE) (RGB)	-1577	6	3-1
(11)	W-71	Gray Sky, Thunderstorm Coming (to S) (RGB)	-1577	7	3-1
(12)	W-72	Water Under Nimbus Clouds (RGB)	-1577	8	3-1
(13)	W-73	Seaweed; Scene of Seaweed in Water (telephoto; sunlight, hazy, gray clouds) (RGB)	-1577	9	3-1
(14)	W-73	Water; Scene of Seaweed in Water (telephoto; sunlight, hazy, gray clouds) (RGB)	-1577	10	3-1
(15)	W-300	Muddy Water, Normal Exposure (RGB)	-1583	12	3-1
(16)	W-301	Muddy Water, Over Exposure (RGB)	-1583	11	3-1
(17)	W-302	Muddy Water, Over Exposure (RGB)	-1583	10	3-1
(18)	W-177	Cumulus White Cloud, Under Exposure (BR)	-1583	6	3-1
(19)	W-178	Cumulus White Cloud, Normal Exposure (BR)	-1583	5	3-1
(20)	W-179	Cumulus White Cloud, Over Exposure (BR)	-1583	4	3-1
(21)	W-180	Blue Sky, Under Exposure (BR)	-1583	9	3-1
(22)	W-181	Blue Sky, Normal Exposure (BR)	-1583	8	3-1
(23)	W-182	Blue Sky, Over Exposure (BR)	-1583	7	3-1
(24)	W-80	Leaves of Sycamore (Platanus occidentalis, L.) Yellow (RGB)	-1578** -1749	4 4	3-1 8-2
(25)	W-81	Leaves of Sycamore (Platanus occidentalis, L.) Yellow Close-up (RGB)	-1578	5	3-1
(26)	W-121	Leaves of Sycamore (Platanus occidentalis, L.) Green (RGB)	-1578	6	3-1
(27)	W-122	Leaves of Sycamore (Platanus occidentalis, L.) Green Close-up (RGB)	-1579** -1749	4 5	3-1 8-2
(28)	W-123	Leaves of Black Oak (Quercus velutina, Lam.) Green (RGB)	-1579** -1749	5 6	3-1 8-2
(29)	W-131	Leaves of Black Oak (Quercus velutina, Lam.) Green Close-up (RGB)	-1579** -1749	6 7	3-1 8-2
(30)	W-143	Green Vegetation, Leaves in Light, Normal Exposure (GB)	-1582	8	3-1

**Spectrophotometric curve in error, see next indicated GE graph sheet.

Index to Appendix C (continued)

Sample Number	Exposure Number	Description	GE Graph Sheet Serial No. and Curve No. Visible Spectrum	Curve Number	Date Measur
(31)	W-143	Green Vegetation, Leaves in Shade, Normal Exposure (GB)	GE II-1582	9	3-17-5
(32)	W-144	Green Vegetation, Leaves in Light, Over Exposure (GB)	-1582	6	3-17-5
(33)	W-144	Green Vegetation, Leaves in Shade, Over Exposure (GB)	-1582	7	3-17-5
(34)	W-145	Green Vegetation, Leaves in Light, Over Exposure (GB)	-1582	4	3-17-5
(35)	W-145	Green Vegetation, Leaves in Shade, Over Exposure (GB)	-1582	5	3-17-5
(36)	W-174	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Light Under Exposure (BR)	-1582	14	3-17-5
(37)	W-174	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Shade Under Exposure (BR)	-1582	15	3-17-5
(38)	W-175	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Light Normal Exposure (BR)	-1582	12	3-17-5
(39)	W-175	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Shade Normal Exposure (BR)	-1582	13	3-17-5
(40)	W-176	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Light Over Exposure (BR)	-1582	10	3-17-5
(41)	W-176	Green Hedge of Black Walnut (Juglans nigra, L.) and Locust (Robinia pseudoacacia, L.) Leaves in Shade Over Exposure (BR)	-1582	11	3-17-5
(42)	W-872	Wet Sand, Normal Exposure (RGB)	-1567	6	2-23-5
(43)	W-873	Wet Sand, Over Exposure (RGB)	-1567	5	2-23-5
(44)	W-874	Wet Sand, Over Exposure (RGB)	-1567	4	2-23-5
(45)	W-890	Wet Sand, Normal Exposure (RG)	-1568	9	2-24-5
(46)	W-891	Wet Sand, Over Exposure (RG)	-1568	8	2-24-5
(47)	W-892	Wet Sand, Over Exposure (RG)	-1568	7	2-24-5
(48)	W-899	Wet Sand, Normal Exposure (GB)	-1568	12	2-24-5
(49)	W-900	Wet Sand, Over Exposure (GB)	-1568	11	2-24-5
(50)	W-901	Wet Sand, Over Exposure (GB)	-1568	10	2-24-5
(51)	W-881	Wet Sand, Normal Exposure (BR)	-1568	6	2-24-5
(52)	W-882	Wet Sand, Over Exposure (BR)	-1568	5	2-24-5
(53)	W-883	Wet Sand, Over Exposure (BR)	-1568	4	2-24-5

Index to Appendix C (continued)

Sample Number	Exposure Number	Description	GE Graph Sheet Serial No. and Curve No. Visible Spectrum	Curve Number	Date Measur
(54)	W-935	Wet Sand, Normal Exposure (R)	GE II-1569	12	2-24-5
(55)	W-936	Wet Sand, Over Exposure (R)	-1569	11	2-24-5
(56)	W-937	Wet Sand, Over Exposure (R)	-1569	10	2-24-5
(57)	W-926	Wet Sand, Normal Exposure (G)	-1569	9	2-24-5
(58)	W-927	Wet Sand, Over Exposure (G)	-1569	8	2-24-5
(59)	W-928	Wet Sand, Over Exposure (G)	-1569	7	2-24-5
(60)	W-908	Wet Sand, Normal Exposure (B)	-1569	6	2-24-5
(61)	W-909	Wet Sand, Over Exposure (B)	-1569	5	2-24-5
(62)	W-910	Wet Sand, Over Exposure (B)	-1569	4	2-24-5
(63)	W-917	Wet Sand, Normal Exposure (Plena)	-1567	9	2-23-5
(64)	W-918	Wet Sand, Over Exposure (Plena)	-1567	8	2-23-5
(65)	W-919	Wet Sand, Over Exposure (Plena)	-1567	7	2-23-5
(66)	W-875	Dry Sand, Normal Exposure (RGB)	-1570	6	2-28-5
(67)	W-876	Dry Sand, Over Exposure (RGB)	-1570	5	2-28-5
(68)	W-877	Dry Sand, Over Exposure (RGB)	-1570	4	2-28-5
(69)	W-893	Dry Sand, Normal Exposure (RG)	-1571	9	2-28-5
(70)	W-894	Dry Sand, Over Exposure (RG)	-1571	8	2-28-5
(71)	W-895	Dry Sand, Over Exposure (RG)	-1571	7	2-28-5
(72)	W-902	Dry Sand, Normal Exposure (GB)	-1571	12	2-28-5
(73)	W-903	Dry Sand, Over Exposure (GB)	-1571	11	2-28-5
(74)	W-904	Dry Sand, Over Exposure (GB)	-1571	10	2-28-5
(75)	W-884	Dry Sand, Normal Exposure (BR)	-1571	6	2-28-5
(76)	W-885	Dry Sand, Over Exposure (BR)	-1571	5	2-28-5
(77)	W-886	Dry Sand, Over Exposure (BR)	-1571	4	2-28-5
(78)	W-938	Dry Sand, Normal Exposure (R)	-1572	12	3- 1-5
(79)	W-939	Dry Sand, Over Exposure (R)	-1572	11	3- 1-5
(80)	W-940	Dry Sand, Over Exposure (R)	-1572	10	3- 1-5
(81)	W-929	Dry Sand, Normal Exposure (G)	-1572	9	3- 1-5
(82)	W-930	Dry Sand, Over Exposure (G)	-1572	8	3- 1-5
(83)	W-931	Dry Sand, Over Exposure (G)	-1572	7	3- 1-5
(84)	W-911	Dry Sand, Normal Exposure (B)	-1572	6	3- 1-5
(85)	W-912	Dry Sand, Over Exposure (B)	-1572	5	3- 1-5
(86)	W-913	Dry Sand, Over Exposure (B)	-1572	4	3- 1-5
(87)	W-920	Dry Sand, Normal Exposure (Plena)	-1570	7	2-28-5
(88)	W-921	Dry Sand, Over Exposure (Plena)	-1570	8	2-28-5
(89)	W-922	Dry Sand, Over Exposure (Plena)	-1570	9	2-28-5
(90)	W-944	Wet Gravel, Normal Exposure (RGB)	-1573	6	3- 1-5
(91)	W-945	Wet Gravel, Over Exposure (RGB)	-1573	5	3- 1-5
(92)	W-946	Wet Gravel, Over Exposure (RGB)	-1573	4	3- 1-5

Appendix D

Table Indicating Measured Area of Color Transparencies

Table of orientation and film holder scale values for eighty-five samples of color transparencies of natural objects; such as, sky, clouds, water, green vegetation, wet and dry sand, and wet gravel. Included is Figure 31, used to indicate the actual area of the color transparency which was measured.

Figure 31. Grid to indicate the actual area of the color transparency which was measured. To use the diagram and data: (1) Place the color transparency on the coordinate grid, (2) Check that the correct side of the film is towards the observer, (3) Check that the positioning of the number is correct, (4) Move lower right corner of film to indicated H and V values, and (5) The position of the measured area of the color transparency is indicated by the open area within the cross-hatched square above and to the left of the grid.

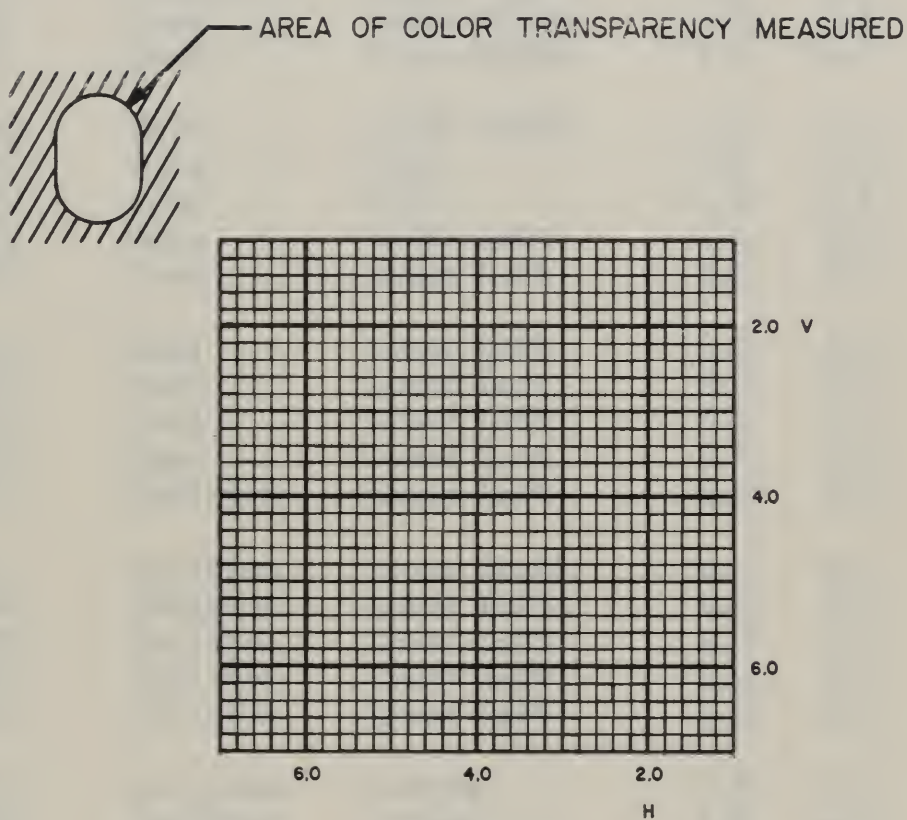

FIGURE 31

Color Transparency Orientation and Film Holder Scale Values for the Indicate Color Transparencies.

Sample Number	Exposure Number	Side of Film Toward Source	Position of Inked Exposure No.	Film Holder Scale Value H	V	S
(8)	W-68	Base	Upper Right	4.4	4.2	4.3
(9)	W-69	Base	Upper Right	4.4	4.2	4.3
(10)	W-70	Base	Upper Right	4.4	4.2	4.3
(11)	W-71	Emulsion	Lower Right	4.4	4.2	4.3
(12)	W-72	Emulsion	Lower Right	4.4	4.2	4.3
(13)	W-73	Base	Lower Right	3.6	3.7	4.2
(14)	W-73	Base	Lower Right	5.2	4.7	4.2
(15)	W-300	Base	Upper Right	5.6	2.9	4.2
(16)	W-301	Base	Top	5.6	2.9	4.2
(17)	W-302	Base	Top	5.6	2.9	4.2
(18)	W-177	Base	Lower Left	5.4	4.7	4.3
(19)	W-178	Base	Lower Left	5.4	4.7	4.3
(20)	W-179	Base	Lower Left	5.0	4.7	4.3
(21)	W-180	Base	Lower Left	5.6	2.9	4.2
(22)	W-181	Base	Lower Left	5.6	2.9	4.2
(23)	W-182	Base	Lower Left	5.6	2.9	4.2
(24)	W-80	Emulsion	Lower Left	4.6	4.7	4.3
(25)	W-81	Emulsion	Lower Right	4.1	4.6	4.2
(26)	W-121	Emulsion	Lower Left	4.6	4.6	4.2
(27)	W-122	Emulsion	Lower Left	4.6	4.5	4.3
(28)	W-123	Emulsion	Lower Left	4.0	4.0	4.3
(29)	W-131	Emulsion	Lower Left	4.0	4.0	4.3
(30)	W-143	Emulsion	Bottom	6.8	2.8	4.2
(31)	W-143	Emulsion	Bottom	6.4	4.4	4.3
(32)	W-144	Base	Lower Right	5.6	3.0	4.2
(33)	W-144	Base	Lower Right	5.2	4.6	4.3
(34)	W-145	Base	Lower Right	5.6	3.0	4.2
(35)	W-145	Base	Lower Right	5.2	4.6	4.3
(36)	W-174	Base	Lower Right	5.8	2.8	4.3
(37)	W-174	Base	Lower Right	4.0	4.0	4.3
(38)	W-175	Base	Lower Right	5.4	3.5	4.3
(39)	W-175	Base	Lower Right	4.0	4.6	4.3
(40)	W-176	Base	Lower Right	5.4	3.5	4.3
(41)	W-176	Base	Lower Right	4.0	4.6	4.3
(42)	W-872	Emulsion	Right	4.4	4.3	4.3
(43)	W-873	Emulsion	Right	4.4	4.4	4.3
(44)	W-874	Emulsion	Right	4.4	4.4	4.3

Sample Number	Exposure Number	Side of Film Toward Source	Position of Inked Exposure No.	Film Holder Scale Value H	V	S
(45)	W-890	Emulsion	Right	4.4	4.3	4.2
(46)	W-891	Emulsion	Right	4.4	4.3	4.2
(47)	W-892	Emulsion	Right	4.4	4.3	4.2
(48)	W-899	Emulsion	Right	4.2	4.2	4.3
(49)	W-900	Emulsion	Upper Left	4.2	4.2	4.3
(50)	W-901	Emulsion	Upper Left	4.2	4.2	4.3
(51)	W-881	Emulsion	Right	4.4	4.3	4.2
(52)	W-882	Emulsion	Right	4.4	4.3	4.2
(53)	W-883	Emulsion	Right	4.4	4.3	4.2
(54)	W-935	Emulsion	Right	4.5	4.0	4.3
(55)	W-936	Emulsion	Right	4.5	4.0	4.3
(56)	W-937	Emulsion	Right	4.5	4.0	4.3
(57)	W-926	Emulsion	Right	4.5	4.0	4.3
(58)	W-927	Emulsion	Right	4.5	4.0	4.3
(59)	W-928	Emulsion	Right	4.5	4.0	4.3
(60)	W-908	Emulsion	Lower Right	4.9	3.8	4.2
(61)	W-909	Emulsion	Lower Right	4.9	3.8	4.2
(62)	W-910	Emulsion	Lower Right	4.9	3.8	4.2
(63)	W-917	Emulsion	Upper Left	4.4	4.3	4.3
(64)	W-918	Emulsion	Upper Left	4.4	4.3	4.3
(65)	W-919	Emulsion	Upper Left	4.4	4.3	4.3
(66)	W-875	Emulsion	Lower Right	4.4	4.1	4.3
(67)	W-876	Emulsion	Lower Right	4.4	4.1	4.3
(68)	W-877	Emulsion	Lower Right	4.4	4.1	4.3
(69)	W-893	Emulsion	Lower Right	4.5	3.9	4.2
(70)	W-894	Emulsion	Lower Right	4.5	3.9	4.2
(71)	W-895	Emulsion	Lower Right	4.5	3.9	4.2
(72)	W-902	Emulsion	Lower Right	4.3	4.1	4.3
(73)	W-903	Emulsion	Right	4.3	4.1	4.3
(74)	W-904	Emulsion	Right	4.3	4.1	4.3
(75)	W-884	Emulsion	Lower Right	4.4	4.0	4.2
(76)	W-885	Emulsion	Lower Right	4.4	4.0	4.2
(77)	W-886	Emulsion	Lower Right	4.4	4.0	4.2
(78)	W-938	Emulsion	Top	4.2	4.3	4.3
(79)	W-939	Emulsion	Top	4.2	4.3	4.3
(80)	W-940	Emulsion	Top	4.2	4.3	4.3
(81)	W-929	Emulsion	Right	4.1	4.0	4.3
(82)	W-930	Emulsion	Right	4.1	4.0	4.3
(83)	W-931	Emulsion	Right	4.1	4.0	4.3
(84)	W-911	Emulsion	Right	4.4	3.6	4.3

Sample Number	Exposure Number	Side of Film Toward Source	Position of Inked Exposure No.	Film Holder Scale Value H	V	S
(85)	W-912	Emulsion	Right	4.4	3.6	4.3
(86)	W-913	Emulsion	Right	4.4	3.6	4.3
(87)	W-920	Emulsion	Upper Left	4.4	4.1	4.3
(88)	W-921	Emulsion	Upper Left	4.4	4.1	4.3
(89)	W-922	Emulsion	Upper Left	4.4	4.1	4.3
(90)	W-944	Emulsion	Top	4.1	4.2	4.3
(91)	W-945	Emulsion	Top	4.1	4.2	4.3
(92)	W-946	Emulsion	Top	4.1	4.2	4.3

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